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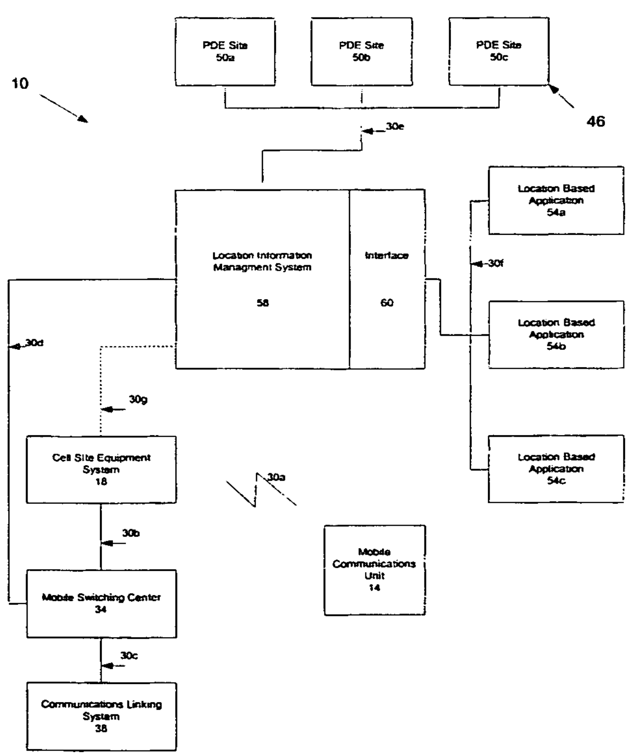
# (54) Title: MANAGING WIRELESS LOCATION INFORMATION IN A MULTI-SOURCE ENVIRONMENT




**(57) Abstract:** The inventive system allows for more efficient use of resources for providing location information in a wireless network (10) where multiple sources (50a-c) of such information may be available. In particular, the system provides a gateway between a plurality of location-based applications (54a-c) and the multiple sources (50a-c) to provide location information for a mobile communications unit (14) located within the wireless network (10). The gateway, or location information management system (58), receive location requests having one or more specifications regarding the desired location information form the location based applications (54a-c). The gateway utilizes these specifications to select one or more of the various sources (50a-c) to provide location information for a mobile communications unit (14). Selection of sources (50a-c) is limited to those sources (50a-c) that match the specifications within the request. Once the desired information is obtained, the information is made available to the requesting application (54a-c).

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# MANAGING WIRELESS LOCATION INFORMATION IN A MULTI-SOURCE ENVIRONMENT

## BACKGROUND OF THE INVENTION

Wireless communications networks generally allow for voice and/or data communication between wireless stations, e.g., wireless telephones (analog, digital cellular and PCS), pagers or data terminals that communicate using RF signals. In recent years, a number of location-based service systems have been implemented or proposed for wireless networks. Such systems generally involve determining location information for a wireless station and processing the location information to provide an output desired for a particular application. Location-based service applications generally involve comparing a current (or recent) location to a location of interest, e.g., a point identified by geographical coordinates, a boundary, or a predefined service zone definition, to make a binary determination (e.g., that the mobile unit is either inside or outside of a zone under consideration), a matching determination (e.g., that the mobile unit location matches or overlaps one or more stored zone definitions) or a proximity determination (e.g., to identify the closest service provider(s)).

Examples of such existing or proposed applications include emergency or "911" applications, location dependent call billing, cell-to-cell handoff and vehicle tracking. In 911 applications, the location of a wireless station is determined when the station is used to place an emergency call. The location is then used to route the call to an appropriate Public Safety Answer Point (PSAP) and/or transmitted to a local emergency dispatcher to assist in responding to the call. In typical location dependent call billing applications, the location of a wireless station is determined, for example, upon placing or receiving a call. This location is then transmitted to a billing system that determines an appropriate billing value based on the location of the wireless station. In handoff applications, wireless location is determined in order to coordinate handoff of call handling between network cells. Vehicle tracking applications are used, for example, to track the location of stolen vehicles. In this regard, the location of a car phone or the like in a stolen vehicle can be transmitted to the appropriate authorities to assist in recovering the vehicle.

From the foregoing, it will be appreciated that location-based service systems involve position determining equipment (PDE) and location-related applications. To some extent, the PDEs and applications have developed independently. In this regard, a number of types of PDEs exist and/or are in development. These include so-called angle of arrival (AOA) time difference of arrival (TDOA), handset global positioning system (GPS) and the use of cell/sector location. The types of equipment employed and the nature of the information received from such equipment vary in a number of ways. First, some of these equipment types, like GPS, are wireless station-based whereas others are "ground-based," usually infrastructure-based. Some can determine a wireless station's location at any time via a polling process, some require that the station be transmitting on the reverse traffic channel (voice channel), and others can only determine location at call origination, termination, and perhaps registration. Moreover, the accuracy with which location can be determined varies significantly from case to case. Accordingly, the outputs from the various PDE's vary in a number of ways including data format, accuracy and timeliness.

The nature of the information desired for particular applications also varies. For example, for certain applications such as 911, accuracy and timeliness are important. For the applications such as vehicle tracking, continuous or frequent monitoring independent of call placement is a significant consideration. For other applications, such as call billing, location determination at call initiation and call termination or during handoff is generally sufficient.

Heretofore, developers have generally attempted to match available PDEs to particular applications in order to obtain the location information required by the application. This has not always resulted in the best use of available PDE resources for particular applications. Moreover, applications designed to work with a particular PDE can be disabled when information from that PDE is unavailable, e.g., due to limited coverage areas, malfunctions or local conditions interfering with a particular PDE modality. In addition, the conventional query and response mode of operation between applications and the associated PDEs has resulted in the use by applications

of PDE dependent data formats, PDE limited data contents, and single PDE input location determinations.

Further, incoming location information requests have only been able to limit the location information provided by the PDEs to a maximum allowable uncertainty and/or location information no older than a specified value. This has not always resulted in the most efficient use of PDEs in a mobile communications system or resulted in the best use of available resources for a particular wireless location application. For example, some applications such as 911 may desire/require the most current location information with the highest level of geographical accuracy. In contrast, the needs of other applications such as a fleet tracking system may be met by using less current and/or less geographically accurate location information. As will be appreciated, even if one or more limiting specifications are contained in a location request, multiple sources of location information may be available to provide the desired information. For example, within certain areas of existing networks, a plurality of network-based Location Determination Technologies (LDT), e.g., multiple types of Position Determination Equipment (PDE) and/or a Serving Mobile Location Center (SMLC), are available to provide location information for mobile units, requiring some method for selecting between the available options.

## SUMMARY

The present invention is directed to allowing for more efficient use of resources for providing location information where multiple sources of such information may be available. Heretofore, many location-based service applications have been developed as part of integrated systems involving specific location finding equipment (LFE)/position determination equipment (PDE) and a dedicated interface between such equipment and the application supported by the equipment. Accordingly, the developers of these systems have generally not addressed issues relating to arbitrating between multiple location sources, nor have these developers recognized any opportunities for optimizing the use of multiple available resources.

More recently, some developers such as SignalSoft Corporation of Boulder, Colorado, have begun developing systems that can utilize different

location sources, alone or in combination. Such systems may be implemented in connection with a gateway between multiple sources of location information and one or more location-based service applications. Alternatively, such functionality may be implemented in connection with an SMLC, PDE, by particular applications or in connection with other network elements. While many service providers have recognized advantages of such systems, such attention has generally focused on simplification of application development, shortened development cycles/improved time to market, improved ability to service a greater number of subscribers independent of handset capabilities, increased geographic coverage areas for location-based service applications, reduced compatibility concerns relating to varying network and infrastructure environments, and potentially increased accuracy of location determination.

The present invention is based in part on the recognition that the ability to access multiple sources of location information also enables efficient management of multiple sources, e.g., avoiding unnecessary source invoke requests, selecting a preferable source or sources for a particular location request, and intelligently using certain sources in concert for enhanced efficiency. This may be achieved in connection with a location gateway system or in any other multiple source environment.

Invoking different location sources often entails consumption of different resources. Such resources may be system resources, e.g., processing resources, messaging traffic, bandwidth or other finite system resources, or may involve pecuniary resources, e.g., in the event that a location source system provides charges for access to location information based on usage. With regard to system resources, it will be appreciated that different sources have different requirements. For example, invoking a network-based PDE may require substantial messaging involving multiple equipment sites coupled with substantial processing. Invoking a GPS or network-assisted GPS system may also require significant messaging and processing as well as use of limited air interface bandwidth. By contrast, accessing internal network information may entail minimal additional burden to network resources, as such information may already reside in the network and be available at a gateway or other relevant service platform.

Similarly, different location sources may involve different lag times between invoking a source or otherwise initiating access and obtaining the desired information. For example, obtaining location information from a network (non-handset) based multilateration PDE may involve transmitting an invoke request to an associated controller, accessing network registers to route a signal to the mobile unit, transmitting a force access signal to the mobile unit, receiving signals from the unit at multiple equipment sites, receiving inputs from the multiple sites and verifying that sufficient information has been received, processing the inputs to determine the mobile unit location and reporting the information to the requesting platform. Each step in this process may contribute to the resulting lag time. By contrast, for example, Cell ID information may be available substantially immediately at the platform or may be quickly obtained from a Home Location Register (HLR) or via other network elements (e.g., an MSC or SCP) messages.

A first aspect of the present invention is embodied in a method for efficiently providing location information on a mobile communications unit (e.g., wireless telephones, pagers, data terminals) of a mobile communications system (e.g., a wireless communications network). The method generally includes the step of determining at least the general location of a particular-mobile communications unit. This information is then used to determine if any of a plurality of position determination equipment sites may be utilized to provide location information on this particular mobile communications unit.

Various refinements exist of the features noted in relation to the subject first aspect of the present invention. Further features may also be incorporated in the subject first aspect of the present invention as well. These refinements and additional features may exist individually or in any combination. The mobile communications system may include a plurality of cells. Each of these cells may encompass a certain geographical area. Typically when the mobile communications unit is being powered or is in an "on" condition, one or more signals will be exchanged on some basis (e.g., intermittently, periodically) between the mobile communications unit and the cell site equipment (e.g., one or more of a transmitter, receiver, transceiver, or antenna(s)) of the cell in which the mobile communications unit is then

physically located. It may be possible for the mobile communications unit to be in this type of communication with multiple cells. Therefore, determining which cell(s) the mobile communications unit is currently communicating with in the above-noted manner may be used to define the general location of the mobile communications unit in accordance with the subject first aspect. That is, the "general location" of the mobile communications unit in accordance with the first aspect may correspond with the area of each of the cells which are in communication with the mobile communications unit in the above-noted manner. Where a cell includes a plurality of cell sectors, this same general technique may be utilized to determine which cell sector(s) is in communication with the mobile communications unit in the above-noted manner.

Another way of conceptualizing the "general location" is that it encompasses a first area. Knowledge of the geographical description of this first area may be used as a basis for determining which position determination equipment site, if any, includes a coverage area which at least overlaps with this first area.

The determination of which position determination equipment site, if any, would be able to provide location information on a mobile communications unit may entail consulting a database or other appropriate data storage structure having information on these position determination equipment sites. Various types of information may be stored on each position determination equipment site within this database. There will typically be an identifier which is unique to each particular position determination equipment site, and this information will typically be stored in the noted database. All other information relating to a particular position determination equipment site will then typically be stored in relation to or in association with its corresponding identifier.

Additional information which facilitates the determination of whether a position determination equipment site is available or appropriate for providing location information on a particular mobile communications unit is the geographical description of the coverage area for the particular position determination equipment site. This geographical description of the coverage area may be defined by the physical location of the position determination

equipment site (e.g., a latitude and longitude coordinate) and some type of specified function (e.g. an equation for an area of a circle and which includes the relevant radius/diameter). Other ways of defining this geographical description may be implemented as well, such as by providing geographical coordinates which define the perimeter of the coverage area. In any case, knowledge of the general location of the mobile communications unit allows the database to be consulted to determine if the coverage area of any position determination equipment site includes at least part of, or more preferably encompasses, this general location.

Another way in which the first aspect of the present invention may be implemented is to store information on all of the position determination equipment sites that are available for providing location information for a mobile communications unit when within a particular cell or cell sector. Information on position determination equipment sites of this type can be stored for one or more cells and/or cell sectors within the mobile communications network, and more preferably for each of these cells or cell sectors. This may be implemented by one or more appropriately configured databases where each "record" in the database could be on a particular cell or cell sector, and which could then include at least an identification of those position determination equipment sites that are associated with the subject cell or cell sector (e.g., a server address). As noted above, the cell/cell sector of the subject mobile communications unit may be determined such that this database may be consulted to determine which position equipment sites, if any, would be available for providing location information on the mobile communications unit at issue.

Information may also be stored on one or more, and preferably each of, the mobile communications units that are part of the mobile communications network. A database or database structure may be used for this purpose as well. Information that may be stored on a mobile communications unit specific basis and that may be useful in implementing the first aspect is whether or not a particular mobile communications unit has handset-based location finding capabilities, such as GPS. The first aspect of the invention could then be adapted to first determine if the mobile communications unit for which location information is desired has handset-based location finding capabilities, and to

consult the cell/position determination equipment site database only if the mobile communications unit of interest does not have handset-based location finding capabilities. This protocol could be reversed whereby the handset-based location finding capabilities of the subject mobile communications unit would only be evaluated if the determination of the general location of the subject mobile communications unit first led to a determination that no position determination equipment site was available for providing the desired location information.

Location information on a mobile communications unit may be requested by one or more location-based systems or applications. Requests for location information may be directed to a location information management system or location manager which acts as a gateway between the location applications and the position determination equipment sites, and also executes the functionality of the subject first aspect. Although the location-based applications may be part of or interface with the mobile communications system in at least some manner, the first aspect contemplates that these location-based applications may be in direct communication with this location information management system as well. That is, any way of operatively interconnecting the location information management system and these location-based applications may be utilized. In any case, the request for location information on a particular mobile communications unit will be relayed by the location information management system to one or more position determination equipment sites only if the location information management system first determines that each such position determination equipment site will be able to actually provide the desired location information. That is, the location information management system will not invoke a request for location information to a particular position determination equipment site unless the location information management system first determines that the position determination equipment site will be able to provide the desired location information on the subject mobile communications unit. Consider the case where there are first, second, and third position determination equipment sites, and where the mobile communications unit is physically located within the coverage area of only the first position determination equipment site. In accordance with the foregoing,

a request for location information will be invoked only in relation to the first position determination equipment site and not the second or third position determination equipment sites. Related to the foregoing, any location information management system associated with the first aspect of the present invention may be configured so as to invoke a request to a particular mobile communications unit for handset-based location information only if any such location information management system first determines that this particular mobile communications unit does indeed have handset-based location finding capabilities.

In a second related second aspect of the present invention, a method is provided for selecting a position determination equipment source from a plurality of position determination equipment sources that are capable of providing location information. The method comprises the steps of: receiving a request for location information for the desired mobile communications unit, where the request includes at least one specification regarding the location information; selecting one position determination equipment source from the plurality of position determination equipment sources based on the specifications; obtaining location information from that position determination equipment source for a specified mobile communications unit; and directing the location information to a location associated with the request (e.g., the requesting parties). The corresponding apparatus of the present invention includes ports for communicating with the requesting party and position determination equipment sources (or a source gateway) and a processor for implementing position determination equipment selection logic as described below. The method and apparatus of the second aspect of the present invention allows a requesting party to request location information that is specifically tailored to its needs. For example, requesting party which require highly accurate geographical location information, such as 911 services, are able to request location information from the position determination equipment sources with the highest "granularity" (i.e., highest resolution) in the system. In contrast, requesting parties with lower quality needs may be able to request location information that has less geographical granularity, which may be older and have a lower cost to the requesting party. Alternatively, in the case where multiple position determination equipment sources are available, the

position determination equipment source may be selected on other/additional bases.

The request for location information on a particular mobile communications unit in association with the method of the second aspect may include one or more requirements or prerequisites relating to the desired location information. This may be characterized as a "quality of service negotiation." Each of these requirements may be evaluated in accordance with the subject aspect of the present invention in relation to determining if any of the position determination equipment sites will be able to provide the location information on the mobile communications unit in accordance with the specified requirements. Each of these QoS parameters may be evaluated individually or in combination to determine if any position determination equipment sources will be able to provide location information for the mobile communications unit in accordance with these parameters. Additionally, some of these QoS parameters may be specified relative to predefined ranges. For example, low, medium and high accuracy geographical location information may be available corresponding to, for example, an accuracy or uncertainty of 700 meters, accuracy between 300 and 700 meters, and accuracy less than 300 meters, respectively. However, it will be appreciated additional value ranges, such as 1 – N, may be used and that each value in the range may be assigned a different accuracy value.

Additional QoS requirements may be specified in the request in addition to geographical accuracies. For, example, another requirement which may be provided along with a request for location information on a particular mobile communications unit is an acceptable cost or price for receiving this location information, and including in the form of a "not to exceed" amount which is specified. If a particular position determination equipment site cannot provide location information on the particular mobile communications unit within the financial constraints imposed by the request, a request for location information on this mobile communications unit will not be invoked to this particular position determination equipment site. Another factor that may be specified in relation to a request for location information is the "age" of the location information. In this case, a database may be utilized which stores the last known location of at least one of, and more preferably

each of, the mobile communications units that are part of the mobile communications network. The second aspect may then be adapted to first consult this information source to determine if the location information that is stored on the mobile communications unit at issue satisfies the corresponding request, and to thereafter proceed with a handset-based position determination evaluation or other position determination equipment site (e.g., network-based) evaluation only if the most recent and stored location information does not satisfy the outstanding request. Likewise, an acceptable response time may be defined in a range of values to allow time sensitive applications, such as 911, to request location information and receive some sort of response in a predetermined time. In this instance, the Location Information Management System may operate such that it provides the best location information available at the end of the specified response time. For example, if when the response time end the only information that the Location Information Management System can provide at that time is cell/sector location information, then cell/sector location will be provided.

In addition or in alternative to specifications that allow a user to specify a range of limitations related to location information, the specification in the request may include instructions on how the Location Information Management System or "gateway" is to operate. For example, the requirement may have a priority field that determines how the gateway will process the request. For example, in the case of emergency service such as 911, there may be a field in the request that specifies highest priority. This highest priority could be a last in, first out command which instructs the gateway to process the request as soon as it is received, in front of other requests in the queue, thus altering the general first in, first out operation of the system. Another requirement that may be utilized with this present invention is a specification for the gateway to use a particular type of position determining equipment source to provide the desired location information. For example, a requesting party may specify that the location information is to come from a TDOA position determination equipment source in the network or, alternatively, it may specify for a particular geographically situated position determination equipment site to provide the location information.

The step of receiving may further involve processing the specification information of the various fields of the location information request for use with the Location Information Management System. For example, a specification within the request may have to be correlated with values relating to certain aspects related to the position determination equipment sources. For instance, where the Location Information Management System operates with a position determination equipment carrier system which employs three different types of position determination equipment sources (e.g., cell/sector, TDOA, AGPS) which provide varying accuracies of location information, a geographical specification in the request (e.g., low, medium, high) may be correlated to a particular type of position determination equipment sources (low = cell/sector, medium = TDOA, high = AGPS).

Once the requirements within the location information request have been correlated to position determination equipment values, the Location Information Management System can select a position determination equipment source to provide the desired location information. Generally, the determination of which position determination equipment source, if any, would be able to provide location information on an mobile communications unit in accordance with the requirements in the location information request may entail consulting a database or other appropriate data storage structure having information on these position determination equipment sources. The Location Information Management System of the present invention will then eliminate from consideration those position determination equipment sources that do not comply with the requirements of the location information request. For example, if the request contains a "not to exceed" cost specification, all the position determination equipment sources with a cost basis higher than specified will be eliminated from consideration. Thus, if a particular position determination equipment source cannot provide location information on a particular mobile communications unit with the required QoS parameters, that particular position determination equipment source will not be considered to provide location information. Though discussed in reference to eliminating position determination equipment sources from consideration, the present invention may also be utilized to affirmatively select only those position

determination equipment sources that meet the QoS parameters for consideration.

Often, only one position determination equipment source will be able to provide the location information requested in accordance with the requirements in a location information request. This is especially likely when there are multiple requirements within the request. However, in some cases, multiple position determination equipment sources may be determined to be available or appropriate for providing location information on a particular MCU (i.e., multiple position determination equipment sources satisfy all the requirements associated with the request for location information on a particular MCU). This may occur, for example, where the only requirement is location information with a cost less than X. In this instance it may still be desirable to only receive location information from a single source; therefore, the remaining position determination equipment sources may be further limited, using some secondary consideration. For example, the first position determination equipment source on the list may be chosen or some secondary QoS specification, such as speed of processing, may be chosen as a default to further limit the number of position determination equipment sources until only one remains. Alternatively, there may be a client profile database that specifies a particular client's preferences as to secondary considerations.

Alternatively or additionally, such position determination equipment selection may be based at least in part on a business rule set. In this regard, a set of rules or an algorithm may be provided for a particular operator, application or the like. For example, the algorithm may specify that, if a particular position determination equipment source is available for the subscriber and/or network area, then that position determination equipment should be utilized. The algorithm may further specify that if the first preferred source is not available then a second identified source should be used if available and so on. Similarly, a location based billing application may specify that CellID information should be used for ongoing monitoring of a subscriber's location until CellID information becomes inadequate to determine whether, for example, the subscriber is inside or outside of a "home zone." More complex algorithms could specify different sources, accuracies,

timeliness, etc. under different conditions or at different times. Such algorithms could be executed by an application or in connection with a gateway or other location platform. In the context of a defined interface for requesting location information, the algorithm could instruct the location platform to ignore attributes specified in the location request or the algorithm could be applied with respect to attributes not populated.

A third aspect of the present invention involves a recognition that, for many location-based applications, it may be desirable to sequentially use one source of location information (i.e., a first position determination equipment source) and then another, based, for example, on the expected resource requirements or time lags associated with those sources. For example, in the case of a binary zone matching application such as location-based billing, a low resource/fast response time source, such as a network source that provides Cell ID information, may first be accessed to obtain low accuracy location information. Although such information may have a lower accuracy, such accuracy may still be sufficient to determine, for example, that a subscriber is well outside his home zone. The need to access a higher resource and/or slower response time source can thus be avoided until the Cell ID information indicates that higher accuracy information is required, e.g., because the coverage area of the identified cell overlaps the home zone.

In other cases, a higher accuracy or slower response time source may be accessed first. For example, because of a favorable business relationship with a given location provider, it may be advantageous to use a relatively accurate source, such as a TDOA source, for periodic monitoring of mobile communications unit location. However, when a location relationship of interest is indicated, a different source may be accessed, e.g., because the service application specifies that source or because information from that source can be most easily handled by a gateway or the service application.

The location information from the first source may also be used to determine not only if, but when the second source is invoked. Thus, in the example above regarding a location-based billing application, Cell ID information is used to determine whether more accurate information is necessary, e.g., in connection with a call placed to or from a subscriber. In a number of applications, including alternative implementations of location-

based billing and applications for monitoring the movements of children, automobiles or other assets, it may be desired to provide notice when a boundary of interest is crossed. In such cases, a first source may be used for monitoring on a periodic or other repeating basis and a second source invoked when necessary, e.g., as a boundary is approached. In this regard, the above aspects of the present invention may be utilized in determining which if any available position determining equipment sources are selected and/or invoked to provide enhanced location information. It will be appreciated that the associated trigger event may be proximity-based or based on some other location relationship rather than boundary crossings. In any event, it will be appreciated that the present invention allows for intelligent use of multiple sources, including for enhanced efficiency.

Thus, in accordance with the third aspect of the invention, a method is provided for use in providing location information regarding mobile communications units in a telecommunications network. The method includes the steps of: receiving a location request including identification information for a mobile communications unit and parameter information (e.g., a business rule set as discussed above) regarding desired location information; obtaining first location information from a first source; comparing the first location information to the parameter information, such as, for example, Quality of Service parameters and/or zone definitions, of the location request; based on the comparison, selectively obtaining second location information from a second source; and providing an output related to the location request. Each of the sources has an expected lag time and expected resource requirement, and at least one of these lag times or resource requirements varies as between the two sources. In many contemplated implementations, the first source will have a lower resource requirement and a shorter lag time and this source will be used for ongoing monitoring purposes. The output may be based on either one or both of the first location information and the second location information. For many implementations, the information from the second source will be used to provide the output.

The output may be provided to the requesting application, to another application (e.g., a billing application), to the mobile communications unit or to any other network node (e.g., to a computer monitoring the movements of a

mobile communications unit or fleet of mobile communications units). The location request may be a specific request, i.e., a one-time only request, such as a request to determine whether an identified mobile communications unit is currently inside or outside of a home zone. On the other hand, the location request may be a general request, i.e., an ongoing monitoring request, such as a request to be notified whenever an identified mobile communications unit crosses a specified boundary or attains another location relationship of interest. In other applications, such as applications that notify all local subscribers of emergency road or weather conditions or provide advertising or other business information to subscribers in a defined area, the location request may identify many subscribers or identify subscribers by type (e.g., all subscribers who have registered for or otherwise agreed to receive certain types of information).

In a further embodiment of the third aspect of the present invention, a first source is used for ongoing monitoring and a second source is used to provide an output. The method includes the steps of: receiving a location request; monitoring information from the first source over time to obtain successive instances of first location information regarding an identified mobile communications unit; performing a comparison to determine whether a location of the mobile communications unit as indicated by the monitored information satisfies a defined relationship relative to stored location information; based on the comparison, selectively obtaining second location information from a second source; and providing an output related to the location request based on the second location information. In one implementation, this method is used in connection with a zone-based service application such as location-based billing or a boundary crossing application. Typically, a low resource source such as a Cell ID source is used to monitor the location of identified mobile communications units on a periodic or other repeating basis. When a relationship of interest such as a boundary crossing or traversal of a home zone definition is indicated, a second, typically more accurate, source is invoked. Thus, the position of the mobile communications unit relative to an area of interest can be monitored on an ongoing basis using a low resource source and a premium source can be reserved for use as necessary.

An apparatus constructed for implementing any or all of the above aspects of the present invention preferably includes: a first interface structure for receiving a location request and providing output to specified locations; a second interface structure for obtaining location information from at least first and second sources; and a processor operative for using the first interface to obtain location requests having one or more parameters specified therein, using the second interface to obtain location information, performing one or more comparison of the first location information to parameter information of the location request and, based on a comparison, using the second interface to obtain the second location information in accordance with one or more comparisons. The processor is further operative for using the second interface to provide an output related to the location request based on at least one of the first location information and second location information. The first interface structure may comprise a processor or processing module configured to define a standardized interface for requesting and providing location information, e.g., to and from a location gateway. The second interface structure may include a port for receiving first location information, e.g., from an MSC, SCP, HLR or other telecommunications structure and/or ports for receiving location information directly from position determination equipment sites or associated controllers. The processor may be any suitable platform associated with or otherwise linked to appropriate structure of the telecommunications network such as an MSC, SCP, or HLR.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and further advantages thereof, reference is now made to the following Detailed Description, taken in conjunction with the drawings, in which:

Figure 1 is a schematic diagram of a wireless network implementing a location information management system in accordance with one or more aspects of the present invention;

Figure 2 is a schematic diagram illustrating a wireless location-based services system in accordance with one or more aspects of the present invention;

Figures 3a-3e illustrate various location finding technologies that may be utilized in the context of the one or more aspects of the present invention;

Figure 4 is a graphical illustration of the use of multiple LFE inputs to reduce location uncertainty in accordance with one or more aspects of the present invention;

Figure 5 is a graphical depiction of a location uncertainty analysis in accordance with one or more aspects of the present invention;

Figures 6-9 illustrate various wireless location interface signaling sequences in accordance with one or more aspects of the present invention.

Figure 10 is a schematic representation of an embodiment of a mobile communications systems which includes or which interfaces with a location information management system;

Figure 11 is one embodiment of a cell/sector structure which may be utilized by the mobile communications system of Figure 10;

Figure 12 is one embodiment of a position determination equipment site database structure which may be utilized by the location information management system of Figure 10;

Figure 13 is an embodiment of a cell/position determination equipment site database structure which may be utilized by the location information management system of Figure 10;

Figure 14 is an embodiment of a HLR database structure which may be utilized by the location information management system of Figure 10;

Figure 15 is an embodiment of a System/PDE capabilities database structure which may be utilized by the location information management system of Figure 10;

Figure 16 is one embodiment of a location information management protocol which may be utilized by the location information management system of Figure 10;

Figure 17 is a schematic diagram of a communications network implementing one embodiment of the present invention;

Figure 18 is a schematic diagram showing a portion of the topology of a wireless network, a home zone and a moving mobile unit to illustrate one application of the present invention;

Figure 19 is a flow chart illustrating a process in accordance with the present invention;

Figure 20 is a messaging sequence diagram illustrating another implementation of the present invention; and

Figure 21 is a illustrative message sequence wherein the zone comparison logic is executed at the application platform.

## DETAILED DESCRIPTION

A number of matters warrant consideration before discussing the various embodiments disclosed in the accompanying drawings. An underlying consideration of the present invention is using multiple PDE/LFE inputs to enhance the location information made available to wireless location-based applications. This use of multiple PDEs allows wireless location-based applications access to information based inputs from PDEs of different types, thereby enhancing the timeliness, accuracy and/or reliability of the requested location information. Moreover, applications that are independent of particular PDEs can access location information from various PDE sources without requiring specific adaptations, data formats, or indeed knowledge of the PDE sources employed, in order to access and use such location information. By virtue of such independence, new location finding technologies can be readily deployed and existing applications can exploit such new technologies without compatibility issues. The combinative use also allows multiple PDE inputs, from one or more PDEs, to be used to allow for wireless station tracking and reduced location uncertainty.

Accordingly a method for utilizing multiple (i.e., two or more) PDEs to provide enhanced location information to support a wireless application is provided in accordance with the present invention. The method involves receiving first and second inputs from first and second PDEs, storing location information based on the inputs in memory, receiving a location request regarding a wireless station from a wireless location application, selectively retrieving the location information from memory, and outputting a response to the location request to wireless location application.

The first and second PDEs preferably may employ different location finding technologies, e.g., GPS, AOA, TDOA, and cell/sector technologies. The stored location information preferably includes at least location information and corresponding time information for particular wireless stations, and may further include location uncertainty information, travel speed information and travel direction information. In response to the location request from the wireless location application, location information may be retrieved from memory or, alternatively, one or more of the PDEs may be prompted to obtain location information. In this regard, the location request may include a specification regarding the desired location information or "quality of service", for example, indicating how recent or how accurate the information should be. If the memory includes information conforming to the specification, then such information is retrieved and output to the requesting application. Otherwise, appropriate information may be obtained by prompting one or more PDEs to locate the wireless station of interest.

Additionally, a processing system is interposed between the PDEs and the wireless location applications such that the applications can access location information in a manner that is independent of the location finding technology employed by the PDEs. The corresponding process implemented by the processing system involves: receiving PDE dependent location data (i.e., location data having a content and/or format dependent on the location finding technology employed) from multiple PDEs receiving a location request from a wireless location application seeking PDE independent location data (i.e., location data having a content and format independent of any particular location finding technology) and responding to the location request based on PDE dependent location data. The process implemented by the processing system may further involve generating and storing PDE independent location data based on the PDE dependent data. The processing system may be resident on the location finding controllers associated with each PDE, on a separate platform and/or the processing system functionality may be distributed over multiple platforms.

In one implementation, multiple PDE inputs may be utilized to make a location determination regarding a wireless station. The corresponding method involves the steps of receiving a first location input from a first PDE

including first location information and first uncertainty information, receiving a second location input from a second PDE including second location information and second uncertainty information and combining the first and second location inputs to provide a combined location input including combined location information and uncertainty information based on the first and second inputs. Preferably, the first and second inputs include raw location and uncertainty information obtained from PDE measurements prior to aggregation and related processing. One or both of the first and second inputs may constitute partial information, insufficient on its own to yield a location and uncertainty regarding the wireless station within the requirements of the wireless location application. For example, in the case of PDEs that determine location based on readings obtained relative to two or more cell sites, a reading from one of the cell sites may be used in conjunction with other location information, e.g., cell sector information, to make a location determination.

In another implementation, multiple PDE inputs, obtained at different times from the same or different PDEs, are utilized to derive tracking information such as for obtaining improved location determination accuracy. The associated method includes the steps of receiving a first PDE input including first location information and first corresponding time information for a particular wireless station, receiving a second PDE input including second location information and second time information for the wireless station, and using the first and second inputs to derive tracking information for the wireless station. The tracking information preferably includes information regarding the mobile station's speed of travel and direction of travel. This tracking information can be used in conjunction with subsequent PDE inputs for the wireless station to improve location determination accuracy and can also be used to interpolate wireless station location between location determinations, or to project future wireless station locations as may be desired for some applications. It will be appreciated that this tracking function and other functions are facilitated by the provision of a system for receiving inputs from one or more PDEs, standardizing such inputs with regard to data content and format, and storing such information. In particular, such standardized and stored information can be readily analyzed to yield derivative information

regarding wireless station position as well as statistical information for wireless stations of interest in the service area.

A system constructed in accordance with the present invention may include an input facility for receiving inputs from multiple PDEs, a memory such as a cache for storing information from the PDE inputs (e.g., a wireless station identification, a location, a time associated with that location, an uncertainty for that location, and travel speed and bearing), an interface for receiving location requests from wireless location applications and providing responses to such requests, and a processing subsystem for processing the PDE inputs and location requests. The system may also include a facility for prompting PDEs to make location measurements in response to location requests. Among other things, the processing subsystem may convert the PDE inputs into a standard format, direct storage of data in the memory, derive tracking or other derivative information from multiple inputs, analyzing stored information relative to received location requests to determine whether the stored information includes information responsive to the requests and selectively directing the PDEs to make location measurements. The system may be resident on a single or multiple platform and the functionality may be spread among multiple applications.

In the following description, particular embodiments and implementations of the above-noted aspects of the present invention are set forth in the context of a telecommunications network. It will be appreciated however, that various aspects of the invention are more broadly applicable to other location based services environments.

Referring to Figure 1, an wireless telecommunications network implementing one or more aspects of the present invention is generally identified by the reference numeral 100. Generally, the network includes a mobile switching center (MSC) 112 for use in routing wireless communications to or from wireless stations 102, a network platform 114 that may or may not be associated with the MSC 112 for implementing a variety of subscriber or network service functions, but which at least is in communication therewith, a variety of location finding equipment (PDE) systems 104, 106, and 108, a cell site equipment system 110, and an IWF (interworking function) system 122. In the illustrated embodiment, the

network platform 114 is used to run a location information management system or Location Manager (LM) 116 in accordance with the present invention and a number of wireless location applications 118. Although the illustrated location manager 116 and wireless location applications 118 are illustrated as being resident on the network platform 114, it will be appreciated that the elements 116 and 118 may be located elsewhere in the network 100, may be resident on the same platform or on separate platforms within the network 100, or the functionality of each of these elements 116 and 118 may be spread over multiple platforms (e.g., individual applications may be on their own platform, including the LM 116). In addition, other applications not depicted in Figure 1 may be resident on the platform 114, on one or more other platforms within the network 100, or both.

As shown in Figure 1, multiple PDE systems 104, 106, and 108 may be associated with the network 100. These PDE systems 104, 106, and 108 may employ any of a variety of location finding technologies such as AOA, TDOA, GPS, EOTD (enhanced observed time difference), TOA (time of arrival)-assisted GPS, and cell/sector technologies, and the various system 104, 106, and 108 may be the same as or different from one another. It will be appreciated that the nature of the data obtained from the PDE systems 104, 106, and 108, as well as the path by which the data is transmitted varies depending on the type of PDE employed, and the ability to accommodate a variety of PDEs is an important advantage of one or more aspects of the present invention. Some types of PDEs include PDE equipment in the handset. Examples include certain GPS and TDOA systems. In such cases, location information may be encoded into signals transmitted from the handset to a cell site or other receiver, and the information may then be transferred to the platform 114 via the MSC 112 or otherwise. Other PDE systems, i.e., embedded systems use equipment associated with individual cell sites such as specialized antennae to make location determinations such as by triangulation and, again, the resulting location information may be transferred to the platform 114 via the MSC 112 or otherwise. Still other PDE systems employ a network of dedicated PDE equipment that is overlaid or integrated relative to the wireless network. Such systems may communicate location information to the platform 114 independent of the MSC 112 and

network cell site equipment. In addition, some PDE technologies can be implemented via equipment resident in the handset, in cell sites or other network locations and/or in dedicated PDE sites such that the data pathway of the location information may vary even for a given PDE technology.

Three of the illustrated systems 104, 106 and 108 operate separate from the MSC 112. For example, such systems may include network based systems AOA and TDOA systems and external systems such as GPS. Generally, the illustrated network based system such as AOA and TDOA systems determine the location of a wireless station 102 based on communications between the wireless station and the cell site equipment of multiple cell sites. For example, and as will be described in more detail below, such systems may receive information concerning a directional bearing of the wireless station 102 or a distance of the wireless station 102 relative to each of multiple cell sites. Based on such information, the location of the wireless station 102 can be determined by triangulation or similar geometric/mathematic techniques. External systems such as GPS systems, determine the wireless station location relative to an external system. In the case of GPS systems, the wireless station 102 is typically provided with a GPS receiver for determining geographic position relative to the GPS satellite constellation. This location information is then transmitted across an air interface to the network 100.

The network 100 further includes a cell site equipment system 110 for communicating with the wireless station 102. In this regard, the cell site equipment system 100 may include three or more directional antennas for communicating with wireless stations within subsections of the cell area. These directional antennas can be used to identify the subsection of a cell where the wireless station 102 is located. In addition, ranging information obtained from signal timing information may be obtained to identify a radius range from the cell site equipment where the wireless station 102 is located, thereby yielding a wireless station location in terms of a range of angles and a range of radii relative to the cell site equipment. This cell/sector location information can be transmitted to the LM 116 via the MSC 112 or possibly via other network elements or structure. Therefore, the cell site equipment system 110 may also be characterized as an PDE. The cell site equipment

system 110 may also communicate with the wireless location applications 118, such as through the MSC 112 and the IWF system 122, or directly through the IWF system 122 (i.e., bypassing the MSC 112).

As shown, the LM 116 receives location information from the various PDE systems 104, 106, 108 and 110. The nature of such information and handling of such information is described in more detail below. Generally, however, such information is processed by the LM 116 to provide location outputs for use by any of various wireless location applications 118 in response to location requests from the application 118. Such applications may include any wireless location services applications such as 911, location information delivery (e.g., closest restaurant), vehicle tracking and location-based billing programs.

Figure 2 illustrates a location-based services system 200 in accordance with one or more aspects of the present invention. An important aspect of one or more aspects of the present invention relates to the operation of the LM 214 to receive inputs from multiple PDEs 202, 204 and 206 and provide location outputs to multiple applications 226, 228 and 230. In accordance with one or more aspects of the present invention, the PDEs 202, 204 and 206 may be based on different technologies, and may therefore provide different types of location information, in different data formats, with different accuracies based on different signals.

A number of different location finding technologies are depicted in Figures 3a-3d for purposes of illustration. Figure 3a generally shows the coverage area 300 of a cell sector. As noted above, the cell site equipment for a particular cell of a wireless telecommunications system may include a number, e.g., three or more, of directional antennas. Each antenna thus covers an angular range relative to the cell site bounded by sides 302. In the case of a three sector cell, each antenna may cover about 120° - 150° relative to the cell site. In addition the coverage range for the antenna defines an outer perimeter 304 of the coverage area 300. As shown, the range varies with respect to angle defining a somewhat jagged outer perimeter 304. Accordingly, the actual uncertainty regarding the location of a wireless station located in the illustrated cell sector is defined by the coverage area 300. The

location determination output from a cell/sector PDE is therefore effectively defined by the coordinates of the coverage area 300.

Figure 3b depicts a TOA based PDE. In this case, the wireless station's range from a cell sector antenna is determined, based on time of signal arrival or signal transit time to within a radius range, e.g., about 1000 meters. Accordingly, the wireless station's location can be determined to be within an area bounded by sides 306 (based on the angular range of the cell sector antenna) and inner 308 and outer 310 arcs (defined by the ranging uncertainty). The output from a TOA based PDE is effectively defined by the coordinates of the sides 306 and the axes 308 and 310.

An AOA based PDE is generally illustrated in Figure 3c. AOA based PDEs determine the location of a wireless station based on the angle of arrival of signals, generally indicated by rays 312 and 314, from the wireless station as measured by two or more cell sites 316 and 318. Each angle measurement has an angular uncertainty generally indicated by line segments 320 and 322. Consequently, the uncertainty region for a given location determination is defined by a polygon having 2n sides, where n is the number of cell sites 316 and 318 involved in the measurement.

Figure 3d illustrates a TDOA based PDE although the illustrated system is cell site based, the TDOA system may alternatively be handset based. In TDOA systems, multiple cell sites measure the time of arrival of signals from a wireless station. Based on such measurements, each cell site can provide information regarding wireless station location in terms of a hyperbola 324 or 326 and an uncertainty, generally indicated by segments 328 and 330. The resulting uncertainty region is defined by a multi-sided region (where each wall is curved) having 2n walls, where n is the number of cell sites involved in the determination.

Figure 3e illustrates a GPS based PDE. In GPS systems, the wireless station includes a GPS transceiver for receiving signals indicating the wireless station's location relative to multiple satellites in the GPS constellation. Based on these signals, the geographic coordinates of the wireless station's location is determined to an accuracy of perhaps 20 meters as generally indicated by circle 332. This information is then transmitted to the wireless network across an air interface.

Referring again to Figure 2, each of the PDEs 202, 204 or 206 outputs location information to its respective LFC 208, 210 or 212. The LFCs 208, 210, 212 could be part of the PDEs 202, 204, 206, could be separate therefrom as shown in Figure 2, or could be part of the LM 214. In any case, the nature of this "raw" PDE output to the LFC depends in part on the type of PDE involved. For example, in the case of a cell sector system the output may be a sector identifier or coordinates; in the case of a TOA system, the output may be a sector identifier or coordinates and a radius; in an AOA system the output may be angular measurements and corresponding cell site identifiers/coordinates; in TDOA systems the output may define multiple hyperbolae; and in GPS systems the output may be geographic coordinates.

The LFCs 208, 210 and 212 collect and aggregate the "raw" location into a standard format which is then sent to the location cache or location cache storage (LC) 220 of the LM 214 for storage. Aggregation involves using the raw data to determine a wireless station location and uncertainty. For some PDE systems, such as GPS systems, this process is simple because location coordinates are reported and the uncertainty is known. For other PDE systems, aggregation is more involved. For example, in the case of TDOA, aggregation may involve receiving multiple hyperbola definitions and using these definitions to define a wireless station location and a multi-sided uncertainty region. The LFCs 208, 210 and 212 may be provided by the PDE vendors or their functionality may be incorporated into a subsystem of the LM 214.

In the context of one or more aspects of the present invention, it is useful to express the location information in a standard format. Accordingly, the LFCs 208, 210 and 212 or a cooperating subsystem of the LM 214 associated with the LC 220, may implement a conversion facility for converting the determined (processed) location information of the LFCs 208, 210 and 212 into standardized location information expressed, for example, as geographical location coordinates and a region of uncertainty. The uncertainty region may be of any shape (e.g., polygonal) depending, for example, on the nature of the PDE(s) employed. Once such type of uncertainty region is a circular region that can be characterized by an uncertainty radius. In the illustrated embodiment, two dimensional location

coordinates are defined (e.g., latitude and longitude) together with an uncertainty radius applied relative to the location coordinates. It will be appreciated that the standard format may allow for altitude coordinates, non-circular uncertainty regions and other parameters.

Referring again to Figures 3a-3e, examples of these coordinates and circular uncertainty regions are graphically depicted. In particular, in each case, a location "L" and standardized uncertainty region "C" are geometrically defined such that the standardized uncertainty region C circumscribes the actual uncertainty region associated with that location finding technology. In this regard, the location L may be defined first (e.g., as the intersection of rays 312 and 314 in Figure 3c) and then the minimum radius circle C may be defined to circumscribe the actual uncertainty region; the standardized uncertainty region C may be defined first (e.g., as the minimum radius circle required to circumscribe the actual uncertainty region) and then L be defined as the center of the circle C; or any other appropriate geometric solutions/approximations may be employed.

This standardized location information is then stored in a database in LC 220. Specifically, the location coordinates for a wireless station and corresponding uncertainties can be stored in a field, in a relational database, or can otherwise be indexed to a wireless station identifier, e.g., a cellular telephone Electronic Serial Number/Mobile Identification Number (ESN/MIN). The coordinates and uncertainty may be expressed in terms of any appropriate units. For example, the coordinates may be expressed as latitude and longitude values in units of $10^{-6}$ degrees and the uncertainty may be expressed in units of meters.

The stored, standardized information can be used to perform a number of multiple input analyses. Three examples of such facilities are generally indicated by the velocity 216, multi-input processing 217 and tracking 218 facilities of LM 214. The velocity facility 216 involves determining and storing speed information and direction (bearing) information for a wireless station based on multiple PDE inputs for the station. Because of the standardized format, such determinations can be easily made relative to inputs from the same or different PDEs 104, 106 and/or 108. The velocity information can be obtained based on knowledge of the change in position and the change in

time (determined by way of the time stamps associated with the location information) and may be expressed in terms of latitudinal and longitudinal velocity components in units of meters per second, together with velocity uncertainty terms. The direction information can be directly obtained from the location information, or can be based on a ratio of the velocity components, using standard trigonometric principles. It will be appreciated that such speed and direction information may be useful for a variety of applications such as vehicle tracking.

The multi-input processing facility 217 can be used to improve location accuracy based on multiple inputs from the same or, more preferably, different PDEs 202, 204 and/or 206. That is, if two locations with two uncertainties can be obtained for a given wireless station at a given time, a reduced uncertainty can be calculated as the overlap of the two original uncertainties. A complicating factor is that the locations and uncertainties stored in the LC 220 for a given wireless station will typically not represent location determinations for the same time. Because wireless stations are generally mobile, an additional element of uncertainty is introduced.

The illustrated multi-input processing facility 217 takes time into account. This is accomplished by:

1. accessing the LC 220 to obtain two (or more) sets of location information for a given wireless station;
2. identifying a location, uncertainty and time for each set of information;
3. determining a time difference between the times of the information sets;
4. calculating an element of location uncertainty associated with the time difference; and
5. applying the calculated element of location uncertainty to the earlier location information to obtain time translated location information.

This time translated location information can then be compared to the later location information in an uncertainty overlap analysis, as described below, to obtain a reduced uncertainty.

Various processes can be employed to calculate the additional, time-related element of location uncertainty. A simple case involves assuming a

maximum rate of travel. For example, a maximum rate of travel of 70 miles per hour may be assumed to account for travel of a mobile phone in a vehicle. The uncertainty associated with an earlier location determination may then be expanded by a value determined by multiplying the maximum rate of travel by the time difference between the two measurements to be compared. Different maximum travel rates may be assumed for different conditions, for example, a lower rate may be assumed for city locations than for suburban locations, a lower rate may be assumed for peak traffic periods, or a lower rate may be assumed for mobile stations that are not generally used on fast moving vehicles. Also, wireless station speed and direction information as described above or other tracking information as described below may be used to reduce the time-related element of uncertainty.

Once such a time translation process has been employed to normalize multiple PDE inputs relative to a given time, an uncertainty overlap analysis can be implemented. Such an analysis is graphically illustrated in Figures 4 and 5. Referring first to Figure 4, the smaller circle represents a location and uncertainty associated with a later PDE input taken to be at time $t_1$. The larger circle 402 represents a location and uncertainty associated with a time translated location information based on an earlier PDE input taken to be at time $t_0$. Circle 402 is illustrated as having a larger uncertainty than circle 400 to account for the additional time and travel related element of uncertainty associated with the time translation. The shaded overlap area 404 represents the reduced uncertainty achieved by using multiple inputs. That is, statistically, if circle 400 represents a 95% confidence level regarding the position of the station at $t_1$ and circle 402 represents a nearly 95% confidence level regarding the position of the station at $t_1$, the position of the station can be determined to be in the shaded area 404 with a high level of confidence.

Figure 5 illustrates a mathematical process for combining the original uncertainties to obtain a more accurate position and uncertainty. Mathematically, the problem is to compute the intersection of the circular uncertainty regions, and express the result as a location with an uncertainty (e.g., a circular uncertainty circumscribing the intersection region). To simplify the mathematics, the geometric arrangement of Figure 4 is translated to provide a first axis (x in Figure 5) that extends through the centerpoints of the

circular uncertainty regions 500 and 502 (generally, the coordinates of the originally determined locations) and an orthogonal axis (y) intersecting the center of the larger (in this case later) circular uncertainty region 502. The mathematical equations for the boundaries of circular uncertainty regions 500 and 502 are:

$$x^2 + y^2 = r_1^2 \qquad (1)$$

$$(x-x_0)^2 + y^2 = r_2^2 \qquad (2)$$

It will be appreciated that the values of $r_1$, $r_2$ and $x_0$ are known as these are the uncertainty of the time translated information, the uncertainty of the later PDE input and the difference between $r_1$ and $r_2$, respectively. Equations (1) and (2) can then be simultaneously solved to obtain x and y, where x is the new location and y is the radius of the new uncertainty region. Finally, these values can be translated back into Earth coordinates. This mathematical analysis can be used for cases where $x \leq x_0$ and $x_0 \leq r_1 + r_2$. In other cases, the most recent or most accurate of the PDE inputs can be utilized.

The illustrated LM 214 also includes a tracking facility 218. Such tracking involves using historical information (at least two sets of location information) and using such information to reduce the uncertainty associated with current measurements. That is, by tracking movement of a wireless station, information can be obtained that is useful in analyzing the uncertainty of current measurements. In a simple case, where tracking information indicates that a wireless station is moving in a straight line (or otherwise on a definable course) or at a constant speed, then curve fitting techniques or other simple algorithms can be employed to obtain a degree of confidence concerning current location. Moreover, interpolation and extrapolation techniques can be employed to determine location at times between measurements or in the future. Such information may be useful to determine when a wireless station crossed or will cross a boundary as may be desired, for example, for location-based billing applications or network management applications (for handling hand-off between adjacent cells). It will thus be appreciated that the information stored in the LC 220 may include wireless

station identifiers, locations, uncertainties, confidence levels, travel speeds, travel directions, times and other parameters. Data may be purged from the LC 220 upon reaching a certain age in order to remove visitor data and other unnecessary data.

The velocity facility 216, multi-input processing facility 217, and tracking facility 218 may use the raw information data transmitted from the PDEs 202, 204 and 206 to the LFCs 208, 210 and 212 in place of, or in addition to, the LFC outputs. For example, the multi-input processing facility 217 may use a hyperbola definition from a TDOA system in combination with an angle from an AOA system (or other combination of partial PDE outputs) if such combination yields an improved location accuracy or otherwise provides a suitable location determination. Similarly, it may be preferred to use the raw data for velocity or tracking calculations as such data is mathematically closer to the moving wireless station and may more accurately reflect station movement.

Referring again to Figure 2, the illustrated system 200 includes a wireless location interface (WLI) 224 that allows wireless location applications 226, 228 and 230 to selectively access information stored in the LC 220 or prompt one or more of PDEs 202, 204 and/or 206 to initiate a location determination. The WLI 224 provides a standard format for submitting location requests to the LM 214 and receiving responses from the LM 214 independent of the location finding technology(ies) employed. In this manner, the applications can make use of the best or most appropriate location information available originating from any available PDE source without concern for PDE dependent data formats or compatibility issues. Moreover, new location finding technologies can be readily incorporated into the system 200 and used by the applications 226, 228 and 230 without significant accommodations for the existing applications 226, 228 and 230, as long as provision is made for providing data to the LC 220 in the form described above.

The WLI 224 of the illustrated implementation allows the applications to include a specification with a location request regarding the desired location information. For example, the specification may include one or more of the following: the timeliness of the location information (e.g., not older than [date

stamp parameter]), the accuracy of the information (e.g., uncertainty not exceeding [uncertainty parameters]), confidence (confidence at least equal to [confidence parameter]). Alternatively, the request may specify the use of the most recent available information, most accurate available information, etc. In addition, the location request can specify whether the request is for one-time only location information or ongoing monitoring of a mobile station, whether the LM 214 should wait for the next available update or force a location determination, whether redundant or unnecessary updates should be filtered (e.g., do not send updates more often than once a minute or if wireless station has moved less than 50 meters), and what the priority of the request is. In this manner, ongoing monitoring may be employed, for example, by applications such as vehicle tracking and 911, and event triggered requests can be used for other applications such as location based billing. In each case, the desired location parameters can be specified.

Figures 6-9 show messaging sequences for various location request situations. Specifically, Figure 6 shows a series of messages for a location request where the application waits for the next available location determination. The process is initiated by transmitting a WLARequestedLocationInvoke message from one of the WLAs to the LC. This message may include parameter fields for Wireless Station Identification, WLA Identification, Location Request Filter, Location Request Mode (check LC or force PDE location determination), Geographic Extremes (where to look for wireless station), Request Priority (processing priority relative to other pending requests) and Fallback Timeout (time that WLA will wait for a current location determination before accepting the information stored in the LC).

In the case of Figure 6, where the WLA waits for the next available location determination, the next message may be a system access or other triggering signal from the wireless station to the PDE. In response, the LFC sends raw location measurement information to the PDE which, in turn, provides a location update to the LC. The LM then responds to the location request from the WLA with a WLARequestLocationReturnResult message. This message may include the following parameters: Geographic Location, Location Uncertainty, Location Determination Technology, Time Stamp, Velocity, Velocity Uncertainty, and Fallback Timeout Occurred Flag.

Figure 7 illustrates a sequence of messages associated with a forced PDE access. The illustrated sequence is initiated by a WLARequestLocationInvoke as described above. In response, the LM transmits a QueryLocationInvoke message to the LFC to force an PDE determination, and the LFC confirms receipt of this message with a QueryLocationReturnResult message. The parameters of the QueryLocationInvoke message may include Wireless Station ID, Geographic Extremes and Measurement Priority (relative to other pending measurement requests). The LFC then sends a One-time Measurement Request message to the PDE to instruct the PDE to obtain location information for the wireless station of interest. In cases where ongoing monitoring is desired, this message may be sent repeatedly or periodically as indicated by multiple arrowheads in the Figure. In order to obtain a location measurement, it is generally necessary to cause the wireless station to transmit an RF signal for detection by the PDE or to communicate location data to the wireless network. This can be achieved by conducting a polling process using an LRF which requests all wireless stations to register. In this regard, the LFC issues a Force System Access message to the LRF which, in turn, transmits the Force System Access message to the wireless station. In response, a system access signal is transmitted by the wireless station and detected by the PDE. The PDE then transmits Location Measurement Information to the LFC. This may be repeated in the case of ongoing monitoring. The LFC provides a Location Update to the LC and, finally, the LM transmits a WLARequestLocationReturnResult as described above to the WLA.

Figure 8 represents the case where a location request can be responded to based on the data stored in the LC. This occurs, for example, where the cached data satisfies the request specification or the request specifically seeks data from the LC. Very simply, the illustrated message sequence involves transmission of a WLARequestLocationInvoke message from the WLA to the LM and a responsive WLARequestLocationReturnResult. It will be appreciated that this case allows for a very fast response. Moreover, it is anticipated that the cached data will be sufficient in many cases for many WLAs.

Figure 9 shows a typical message sequence for the case where a WLA requests ongoing updates regarding the location of a wireless station. The update period is initiated upon transmission of a WLARequestRegisterInvoke message from the WLA to the LM and receiving a WLARequestRegisterReturnResult in confirmation; and terminates upon transmission of a WLARequestUnregisterInvoke message and receiving a WLARequestUnregisterReturnResult in confirmation. The parameters included in the Register message can include the wireless station ID, update interval, whether wireless station access should be forced, etc. As shown in the Figure, the LM receives Location Updates from time-to-time from the Location Determination Technology (LDT). It will be noted that only those Updates occurring between Registration and Unregistration are communicated to the WLA. In this regard, the Updates are communicated from the LM to the WLA via a LMLocationUpdateInvoke message and a LMLocationUpdateReturnResult is transmitted in confirmation.

The system 200 also includes a Geographic Information System (GIS) based module 222 for use in correlating geographic coordinate information to mapping information, e.g., street addresses, service area grids, city street grids (including one-way or two-way traffic flow information, speed limit information, etc.) or other mapping information. For example, it may be desired to convert the geographic coordinates of a 911 call to a street address for use by a dispatcher, or to correlate a call placement location to a wireless network billing zone. In this regard, the GIS module 222 may communicate with the LFCs 208, 210, and 212, the LFC 214 and/or the WLAs 226, 228 and 230 to correlate location information to GIS information, and to correlate GIS information to application-specific information such as wireless network billing zones. A suitable GIS based module 222 is marketed under the trademark MAPS by SignalSoft Corporation of Boulder, Colorado.

One embodiment of a mobile or wireless communications network or system 10 is presented in Figure 10. The mobile communications system 10 includes at least one Mobile Communications Unit 14 (e.g., a cellular phone) which communicates with a cell site equipment system 18 by an appropriate communications link 30a i.e., an RF link. A portion of this cell site equipment system 18 together with associated coverage areas is illustrated in Figure 11.

The cell site equipment system 18 of Figure 2 includes a plurality of cells 22a-h. Each cell 22a-h includes a plurality of cell sectors 26a-c. Each cell 22a-h and its various cell sectors 26a-c cover a certain geographical area. At least one transmitter and at least one receiver (or a "transceiver"), as well as at least one antenna (all not shown), are associated with each cell sector 26a-c for handling all communications involving any Mobile Communications Unit 14 that is physically located within or possibly in proximity to the particular cell sector 26. Typically a single directional antenna will be utilized by each cell sector 26 in the type of configuration presented in Figure 2, and the coverage area of the antennas in a given cell 22 will overlap to a degree. Although each of the cells 22 and cell sectors 26 are illustrated in Figure 2 as being of the same size and configuration, such need not be the case in relation to the functionality of a Location Information Management System 58 which is part of or at least operatively interfaces with the mobile communications system 10, and which is discussed in more detail below. Moreover, adjacent cells 22 may be disposed in overlapping relation without adversely affecting the functionality of the Location Information Management System 58.

An appropriate communications link 30b operatively interconnects the cell site equipment system 58 with a mobile switching center 34 as illustrated in Figure 1. The mobile switching center 34 in turn is operatively interconnected with a communications linking system 38 (e.g., a telephone company central office, one or more central switching offices) by an appropriate communications link 30c. Communications involving the Mobile Communications Unit 14 are thereby directed through the cell site equipment system 18, the mobile switching center 34, and communications linking system 38 to the other device(s) involved in the subject communication. Any way of providing communication capabilities between a given Mobile Communications Unit 14 and another communication device may be employed without adversely affecting the functionality of the Location Information Management System 58.

The Location Information Management System 58 may be directly operatively interconnected with the mobile switching center 34 by an appropriate communications link 30d, and may be directly operatively interconnected with the cell site equipment system 18 by an appropriate

communications link 30g (as indicated by the dashed line in Figure 1), or both. Any way of integrating the Location Information Management System 58 with the mobile communications network or system 10 may be utilized, including such that the Location Information Management System 58 is part of the system 10 or separate therefrom. Multiple components are part of or interface with the Location Information Management System 58 in relation to communications involving any Mobile Communications Unit 14 of the mobile communications system 10 (e.g., communications being directed through the mobile switching center 34). These components may either be part of or separate from the mobile communications system 10. One such component is a position determination equipment system 46 that is operatively interconnected with the Location Information Management System 58 by an appropriate communications link 30e. The PDE system 46 generally provides a source to determine the location of a particular Mobile Communications Unit 14. In this regard, the illustrated PDE system 46 generally includes a plurality of PDE sites 50a-c that may be located at various physical locations throughout the mobile communications system 10. Any technology which is appropriate for determining the location of a given Mobile Communications Unit 14 may be employed at any given PDE site 50. As used herein, a PDE source is used to discuss any source able to provide location information, such as a database and/or PDE sites 50, whereas a PDE site 50 generally entails a fixed network structure for providing location information. Representative examples of position determination technologies which are appropriate for the position determination equipment system 46 include GPS-based technologies, cell sector or micro-cell location technologies, time difference of arrival (TDOA) technologies, angle of arrival (AOA) or other network triangulation technologies, and enhanced observed time difference (EOTD), and TOA or network assisted GPS. It will be appreciated that these technologies may be handset based, network based or network overlay technologies.

Another component which is operatively interconnected with the location information management system 58 by an appropriate communications link 530f is one or more location-based applications 54. Location information regarding a particular mobile communications unit 14

may be desired or required by each of these location-based applications 54 for one or more purposes. Requests for location information from any of the location-based applications 54 is managed through/by the location information management system 58. Although the mobile communications system 10 has been described in accordance with the foregoing structure, the functionality of the location information management system 58 may be integrated in the mobile communications system 10 in any appropriate manner. For instance, the location information management system 58 may be readily adapted for any way of routing mobile or cellular communications.

One function of the location information management system 58 is to store various types of information on each position determination equipment site 50 which is utilized by the location information management system 58 or to otherwise associate cells 22 or cell sectors 26 with those position determination equipment sites 50 that are able to provide location information for a particular mobile communications unit 14 when in this particular cell 22 or cell sector 26.

Figure 12 presents one embodiment of a PDE site database 62 which may be utilized by the Location Information Management System 58 to determine which PDE sites can provide location information for a particular Mobile Communications Unit 14. The database 62 may reside on an appropriate computer-readable storage medium. The PDE site database 62 may be generally viewed as containing a database record 66 for each PDE site 50 utilized by the Location Information Management System 58. Each record 66 may include some or all of the following types of information regarding various QoS parameters, each of which defines its own separate database field: 1) a PDE site field 70 for storing information which identifies and is unique to the subject PDE site 50; 2) a position determination technology type field 74 for storing information which identifies the type of technology which is utilized by the subject PDE site 50 to provide location information on a Mobile Communications Unit 14; 3) a physical location field 78 for storing information on the physical location of the subject PDE site 50; 4) a coverage area field 82 for storing information that defines the geographical area for which the subject PDE site 50 is able to provide location information on Mobile Communications Units 14 (alone or possibly in

combination with information in the corresponding physical location field 78); 5) a position determination accuracy field 86 for storing information which quantifies the accuracy or uncertainty associated with location information on a Mobile Communications Unit 14 which is provided by the subject PDE site 50 or otherwise known; 6) a computational speed field 90 for storing information which quantifies the amount of time required by the subject PDE site 50 to provide location information for a Mobile Communications Unit 14; and 7) a computational cost field 94 for storing information which quantifies the cost for providing location information on a Mobile Communications Unit 14 utilizing the subject PDE site 50. Moreover, other types of information and/or additional QoS parameters may be stored in relation to each PDE site 50, and may then be made available to the Location Information Management System 58. For example, a field may be included which identifies if the PDE site 50 relies upon handset based location technology. As will be appreciated, each record 66 may also contain a blank field 98 such that future modifications to the system may be accommodated. With regard to the coverage area field 82, information contained therein may geographically define the coverage area of the associated PDE site 50. Alternatively, some type of function or parameter may be stored in the coverage area field 82 and which defines the coverage area for the subject PDE site 50 (e.g., information in the coverage area field 82 may be a radius, which when combined with information in the physical location field 78, may be used to define the coverage area of the subject PDE site 50 through an equation for the area of a circle). It will be appreciated that any way of storing the type of information set forth in the PDE site database 62 may be utilized by the Location Information Management System 58. In any case, once the Location Information Management System 58 determines or otherwise receives general location information on a particular Mobile Communications Unit 14 in a manner to be discussed in more detail below, the Location Information Management System 58 may consult the PDE site database 62 to determine if any of the PDE sites 50 stored therein would be able to provide location information on the particular Mobile Communications Unit 14.

Figure 13 presents an embodiment of a cell/PDE site database 72 which may be utilized by the location information system 58 when a general location

of a Mobile Communications Unit 14 is known to determine if location information may be provided on a particular Mobile Communications Unit 14, and which would typically reside on an appropriate computer-readable storage medium. The illustrated cell/PDE site database 72 contains a database record 75 for each cell 22 and/or cell sector 26 that is associated with the Location Information Management System 58. Each record 75 may include one or more of the following types of information, each of which defines its own separate database field: 1) a cell or cell sector field 77 which identifies a particular cell 22 or cell sector 26; and 2) one or more PDE site fields 70, which generally correspond to the PDE site field in the PDE site database and which identify (e.g., via a server address) those PDE sites 50 that are available for providing some sort of location information on a particular Mobile Communications Unit 14 when within the cell 22 or cell sector 26 associated with the particular record 75. Any data storage technique may be utilized, e.g., although the discussion above denotes separate databases, the associated information may be included in or conceptualized as tables of a single relational database. What is of importance is that each cell 22 or cell sector 26 encompassed by the Location Information Management System 58 in the illustrated system be associated with a "list" of PDE sites 50 that would be able to provide location information on a particular Mobile Communications Unit 14 when in this cell 22 or cell sector 26. That is, once the Location Information Management System 58 determines or otherwise receives information on which cell 22 or which cell sector 26 a particular Mobile Communications Unit 14 is currently located in, the Location Information Management System 58 may consult the cell/PDE site database 72 to determine if there are any PDE sites 50 stored in relation to this cell 22 or cell sector 26 so as to be able to provide location information on the particular Mobile Communications Unit 14.

Another function provided by the location information management system 58 is to manage requests for location information on mobile communications units 14 of the mobile communications system 10. Although these requests will typically be invoked by a location-based application 54 which somehow interfaces with the mobile communications system 10, the location information management system 58 contemplates providing location

information on mobile communications units 14 to any "source" which may somehow invoke a request for location information on a given mobile communications unit 14, directly or indirectly, to the location information management system 58. There are principally two "sources" of information of sorts which are utilized by the location information management system 58 to provide location information on a given mobile communications unit 14. One "source" is the above-noted PDE site database 62 of Figure 12 or the cell/PDE site database 72 of Figure 13. In the latter case, this "source" is an association of a particular cell 22 or cell sector 26 with those PDE sites 50 that would be able to provide location information on a particular mobile communications unit 14 when in this particular cell 22 or cell sector 26.

Another source of information that may be utilized by Location Information Management System 58 is a collection of information on each of the various Mobile Communications Units 14 of the mobile communications network 10. One such source is illustrated in Figure 14 and is in the form of a home location register database 130. As in the case of the PDE site database 62 and the cell/PDE site database 72, the home location register database 130 will typically reside on an appropriate computer-readable storage medium.

The home location register database 130 of Figure 14 may be generally viewed as containing a database record 134 on each Mobile Communications Unit 14 of the mobile communications system 10. Each record 134 may include one or more of the following types of information, each of which defines its own separate database field: 1) a mobile unit field 138 for storing information which somehow identifies and which is unique to a particular Mobile Communications Unit 14 (e.g., an Electronic Serial Number (ESN)/ Mobile Identification Number (MIN), or a telephone number, for the subject Mobile Communications Unit 14); 2) a subscriber name field 132 for storing information which identifies the party that has subscribed to the services provided by the mobile communications system 10 in association with the subject Mobile Communications Unit 14; 3) a subscriber address field 136 for storing information which identifies the address of the party that has subscribed to the services provided by the mobile communications system 10 in association with the subject Mobile Communications Unit 14; 4) a position

determination capabilities field 140 for storing information which defines the position determination capabilities of the subject Mobile Communications Unit 14 (e.g., whether the same includes a GPS transceiver or other handset-based location finding capabilities); 5) a physical location field 144 for storing information which identifies the last known physical location of the subject Mobile Communications Unit 14; and 6) a physical location time field 148 for storing information which identifies the time associated with the information contained in the physical location information field 144 (e.g., the physical location information in the field 144 was obtained at a specified time on a specified day in a specified year). It will be appreciated that any way of storing the type of information set forth in the home location register database 130 may be utilized by the Location Information Management System 58. Moreover, other types of information could be stored in relation to each Mobile Communications Unit 14 as well, including further information, which relates to the location information contained in the physical location field 144 (e.g., the accuracy or uncertainty of the specified physical information), and may then be made available to the Location Information Management System 58. The Location Information Management System 58 may consult the home location register database 130 upon receiving a request for location information on a particular Mobile Communications Unit 14 to determine if the particular Mobile Communications Unit 14 itself has location finding capabilities and/or to determine if the last known physical location of the particular Mobile Communications Unit 14 satisfies the outstanding request for location information.

Figure 15 presents an embodiment of a system/PDE capabilities database 160 which may be utilized by the Location Information Management System 58, when a general location of the Mobile Communications Unit is not provided with the location request or otherwise available. The illustrated system/PDE database 160 contains a database record 164 for each type of PDE technology utilized in the PDE system 46 associated with the Location Information Management System 58. Each record 164 may include one or more of the following types of information, each of which defines its own separate database field: 1) PDE type 166; 2) a system average determination accuracy 168; 3) a system average response time 170; 4) a system average

computation cost 172. Each of the entries provides an average value for the particular type of PDE utilized by the PDE system 46. In this regard, if a location information request is received at the Location Information Management System 58 without a general location such that an individual PDE site may not be selected based on that general location, the Location Information Management System 58 may select the type of PDE site 50 in the PDE system 46 that may be utilized to provide the requested information. In this case, the Location Information Management System 58 will produce a request for location information to a platform of the PDE system 46 to locate a particular mobile communication unit 14 using the specified type of position determining equipment. The PDE system 46 then has the responsibility to invoke the designated PDE site 50 covering the area where the Mobile Communications Unit is currently located. As will be appreciated, the PDE system 46 is generally in communication with various components of the mobile network 10 and may therefore be able to determine the mobile communication unit's general location through various known means (e.g., an HLR query, cell identification information messages used for call routing, etc.)

As noted, one function provided by the Location Information Management System 58 is to manage requests for location information for Mobile Communications Units 54 of the mobile communications system 10. Although these requests will typically be transmitted by a location based application 54 which generally interfaces with the Location Information Management System 58 through interface 60, the illustrated system 58 contemplates providing location information for Mobile Communications Units 14 to any authorized party which requests location information for a given Mobile Communications Unit 14, directly or indirectly, from the Location Information Management System 58. Figure 16 presents one embodiment of location information management protocol 700 which may be utilized by the Location Information Management System 58 of Figures 10 for selecting a PDE site 46 to provide location information for a particular Mobile Communications Unit 14 when a general location is provided. The Location Information Management System 58 may include at least one processor for executing the functionality of the protocol 700. However, any way of

appropriately executing the protocol 700 in the context of the mobile communication system 10 may be utilized.

The illustrated protocol 700 of Figure 16 is initiated by receiving (710) a request at the Location Information Management System for location information for a particular Mobile Communications Unit. This request for location information may originate from one of the location based applications 54 or from any source that properly interfaces with the Location Information Management System 58. This request may include one or more requirements or specifications that are associated with the desired location information to be provided by the Location Information Management System 58. In accordance with the present invention, some of these specifications may be in the form of a predefined user selectable ranges of QoS parameters e.g., low, medium, high accuracy. For exemplary purposes, the illustrated protocol implementation assumes that two QoS parameters have been received with the location request, such as a geographical accuracy parameter and time of response requirement.

The location information management protocol 700 of Figure 16 continues searching (720) a location cache associated with the Location Information Management System 558 to determine if the cache includes location information satisfying the requirements of the request. The location cache contains a record on each Mobile Communications Unit 14 within the mobile communication system 10. This record includes information on the last known physical location of the corresponding Mobile Communications Unit as well as a time associated with this last known physical location. This information may be acquired from, for example, a previous location request or through a home location register associated with the Mobile Communications Unit 14. The Location Information Management System 58 searches the location cache to identify the relevant record using for example the Mobile Communications Unit's mobile identification number (MIN). If the information in the record meets all the requirements specified in the request, the information is retrieved from the location cache and directed (730) to the recipient designated by/in the request. In the event that satisfactory location information for a particular Mobile Communications Unit 14 is not currently stored in the location cache, the general location of the Mobile

Communications Unit, if available, is accessed from the request or otherwise obtained and, if necessary, processed to be in a standard format for use with the Location Information Management System 58.

Once a general location of the Mobile Communications Unit 14 is known, the processor associated with the Location Information Management System 58 uses the general location information, such as a cell sector, to search (750) the Cell/PDE database 72 to determine if any local PDE sites 50 are capable of providing location information for the Mobile Communications Unit 14 identified in the request. As will be appreciated, if no PDE are capable to provide location information, the protocol ends. Generally, the database 72 is searched to produce a 'list' of identifiers associated with the PDE sites 50 capable of providing location information for an area that includes at least part of and, more preferably, encompasses the entirety of, the general location of the Mobile Communications Unit 14. Once these PDE identifiers are obtained, they may be used to search records 66 in the PDE site database 62 to identify one or more a PDE sites that can provide the location information.

The illustrated protocol then proceeds by determining if the Mobile Communications Unit 14 is associated with a handset-based position determining equipment site 46. In this instance, the processor associated with Location Information Management System 58 will search (760) a Mobile Communications Unit database 100 which may be a HLR database for a particular Mobile Communications Unit 14 to determine what capabilities are available for the desired Mobile Communications Unit 14. In this regard, if a particular Mobile Communications Unit 14 supports, for example, TDOA position determination but not GPS, the available PDE 50 is correlated with this data and those PDEs which are handset-based, as noted by field 96, that are not supported by the Mobile Communications Unit 14 will be eliminated from consideration.

At this point, all PDE sites 50 capable of providing location information for the Mobile Communications Unit 14 are identified by combining (770) information from the PDE site database and the HLR database in a 'list'. Next, the one or more QoS parameters from the location information request may be compared (780-790) to the list of capable PDE sites to select a site for providing the desired information according to the specified parameters. For

example, in the case where the first QoS parameter specifies a "medium" geographical accuracy, the processor 150 will begin to search the records associated with each listed PDE site 50 to determine if they provide at least medium geographical location information. As will be appreciated, at some point prior to initiation of the protocol 700, the ranges associated with each specification (geographical accuracy, cost, timeliness, etc.) will have been defined. For example, a location request may be provided via interface 60 from a location based application 54 requesting medium geographical accuracy. The Location Information Management System 50 may then convert this specification into a standard format that may be used in accordance with the present invention. For example, in the case of geographical accuracy, the Location Information Management System 58 may be configured such that low accuracy corresponds with an uncertainty of 750 meters or more, medium accuracy is location information with an accuracy between 300 and 750 meters and high geographical accuracy is defined as location information within a 300 meter radius. Accordingly, the protocol compares (780) the first parameter (e.g., medium geographical accuracy) with the corresponding attribute, which is expressed in standard terms, for each PDE site 50. In particular, the database record for each of the identified PDE sites 50 on the list is compared with the parameter. In the case of a parameter requesting medium geographical accuracy, all PDEs which provide low geographical accuracy are eliminated from consideration for selection (high accuracy PDEs may also be eliminated depending on the specific implementation of the protocol, e.g., the protocol may allow for specification of "at least medium" or "only medium"). As will be appreciated, the interface 60 and Location Information Management System 58 may be configured such that any QoS parameter may be assigned a standardized value with and compared to any value in PDE database record 66. For example, low, medium and high geographical accuracies may be correlated with PDE types (i.e., low = cell sector, medium = TDOA, and high = AGPS) and then correlated with the position determination technology type 74 of the database record 66. As will be appreciated, this arrangement provides great flexibility in comparing QoS attributes with PDE capabilities and allows for changes in

system capabilities to be implemented without necessarily changing the QoS parameters used by the location based applications.

If the location request contains a second specification the protocol proceeds to perform an appropriate comparison (790), again limiting the number of PDE sites 50 available to provide the desired location information. Once all such limiting steps of the protocol are completed, a PDE site 50 is selected and invoked (800) to provide the desired location information. It may, of course, turn out that multiple PDE sites 50 will be appropriate for determining the physical location of the Mobile Communications Unit 14. In this case, the Location Information Management System 58 may be configured such that it invokes all identified PDE sites 50 or invokes some sort of default selection criteria to select among the remaining PDE 46 sites. For example, the attributes listed in each PDE's record 56 in the PDE site database 62 may be utilized to select among the remaining PDE sites 50. Thus, in the case where three PDEs are identified as meeting the specifications from the location request, it may be possible to select among the three using a nonspecified attribute such as cost or any other attribute not already specified in the request. Alternatively, a client profile database may be consulted to determine default characteristics for individual clients. Thus, a client application may specify the use of a given PDE (e.g., due to a favorable relationship with that provider) whenever possible.

It of course may turn out that none of the PDE sites 50 will be appropriate for determining the physical location of the mobile communications unit 14 that is associated with the request of step 710 of the location information management protocol 700 of Figure 16. In this case, a response is sent by the location information system 58 which provides at least some type of indication that no location information is available for the mobile communications unit 14 which was the subject of the request of step710. Searching the PDE database 62 and/or the cell/PDE site database 72 in the above-noted manner alleviates the time and expense for invoking a request to a particular PDE site 50 which would be unable to provide the location information on the desired mobile communications unit 14. That is, instead of sending a request for location information on a particular mobile communications unit 14 to each and every PDE site 50 utilized by the location

information management system 58, the location information management system 58 first determines which, if any, of the PDE sites 50 could provide location information on the desired mobile communications unit 14 in accordance with the request of step 710 of the location information management protocol 700. Once the available PDE sites are determined, the location information system 58 identifies the "best" PDE site 50 in accordance with one or more QoS values to provide location information for a particular mobile communications unit 14. Only then does the location information management system 58 invoke a request for location information through execution of step 800 of the location information management protocol 700 of Figure 16.

There are various ways in which a request for location information on a particular mobile communications unit 14 may be invoked through execution of step800. The protocol 700 may be configured such that a request for location information is sent to each PDE site 50 which is identified as being appropriate in step790. A preferable option would be for the location information management protocol 700 to be configured to invoke a request for location information on a particular mobile communications unit 14 in relation to only a single PDE site 50. The location information system 58 may also be configured to somehow "combine" or "aggregate" the location information from multiple PDE sites 50 into a single piece of aggregated location information. In any case, the desired location information is received through execution of step 800 of the location information management protocol 700, and is thereafter transmitted to the desired recipient through execution of step 820 of the protocol 700. It should be appreciated that the location information management system 58 could be configured to have the PDE site 50 of choice send the location information directly to the relevant location-based application 54.

Figures 17 – 21 describe an application in which one or more of the above described methods for selecting among multiple PDE sources is utilized. In the following description, the invention is set forth in the context of particular implementations involving a first source for providing cell ID information and a second source for providing multilateration location information. The cell ID information is generally used first to reduce the

number of instances where the multilateration source is invoked. This has particular advantages for a number of applications as discussed below in that it promotes efficient use of network location resources. It will be readily appreciated, however, that other types of location sources and/or other sequences for accessing multiple location sources may advantageously be utilized in accordance with the present invention. Accordingly, the following description should be understood as exemplifying the invention and not by way of limitation.

Figure 17 illustrates a wireless network 1100 implementing one embodiment of the present invention. In the network 1100, a mobile unit 1102 communicates with cell site equipment 104 via an RF interface 1105. In the illustrated example, the mobile unit 1102 is shown as being a wireless telephone. It will be appreciated, however, that any suitable mobile unit can be utilized including, for example, personal digital assistants, data terminals having a wireless modem, etc. The cell site equipment 1104 may be, for example, a cell sector antenna or the like. In the illustrated network 1100, the cell site equipment 1104 is interconnected to a switch 1106. Although only one piece of cell site equipment 1104 is illustrated, it will be appreciated that switch 1106 may service multiple cells. The switch 1106 may include, for example, a mobile switching center (MSC), Service Control Point (SCP) or any other structure for routing communications between a calling unit and a called unit. Among other things, the switch 1106 is operative for routing calls between the wireless network 1100 and a wireline network 1107 for communications between the mobile unit 1102 and another mobile unit, a wireline unit or a data network node. As will be discussed in more detail below, the switch 1106 may also be operative for generating billing records such as Call Detail Records(CDRs) 1109 for transmission to a billing application of a wireless carrier or other service provider.

Figure 17 also shows a gateway 1108 similar to the Location Information Management System described above, illustrated in connection with the switch 1106. It will be appreciated that such a gateway may be associated with one or more (typically numerous) switches. Moreover, different gateways may service different subscribers, carriers, applications, equipment, network areas, etc. The gateway 1108 may be, for example, a

computer platform for executing a variety wireless network applications. The gateway 1108 may be physically located proximate to the switch 1106 or may be remotely located and interconnected to the switch 1106 by a local area network, wide area network or other communications pathway. The illustrated gateway 1108 includes a processor 1110 for running a source selection and location provisioning application in accordance with the present invention. As will be understood from the description below, a source selection application in accordance with the present invention may be incorporated into location-based services application or may be implemented in connection with a separate gateway (as shown) or other separate functional unit.

In order to implement intelligent source selection, the application running on processor 1110 compares location information to mobile unit location information. Such location information may be stored at the gateway platform, specified by the requesting application or otherwise made available to the processor 1110. In the illustrated embodiment, it is stored in the gateway platform. The stored location information 1112 stores definitions of locations of interest for use by the location-based service applications 1114, 1116 and 1118. The definitions of these locations of interest may be provided in any suitable form. For example, a service zone for a location-based billing application, asset tracking application or the like may be defined as a set of cell identifiers or cell sector identifiers that represent the service zone. Alternatively, the service zone information may be stored as a set of geographical coordinates or geographical boundaries that define the service zone. For cell sector implementations, such geographical information may be converted into current network topology, e.g., cell sector identifiers, at the time of a location comparison. It will be appreciated that other conventions may be utilized for storing a representation of a service zone area.

In addition, it will be appreciated that a GIS system 1120 may be utilized for inputting and formatting the service zone information. For example, a service provider or other person defining a service zone may wish to input service zone boundaries relative to an address, streets or other topological information. A GIS application, such as the MAPS application marketed by SIGNALSOFT Corporation of Boulder, Colorado, may be utilized to receive such inputs and convert the associated service zone definitions into

geographical information formatted for convenient handling by the boundary crossing application. Thus, service zone definitions may be converted from one topological system, e.g., addresses or street boundaries, to another topological system, e.g., geographical coordinates or cell/cell sector identifiers. In any case, the definition of the location of interest as well as the location of a mobile unit may be expressed in terms of a quadtree data structure as described in U.S. Patent No. 6,212,392, entitled "Method for Determining if the Location of a Wireless Communication Device is Within a Specified Area," which is incorporated herein by reference.

Location information regarding the locations of mobile units may also be stored for use by the source selection application. Depending, for example, on the nature of the location finding technology employed, the nature of the received location information and the route by which the information is obtained may vary. For example, in the case of cell sector location information, a cell sector identifier may be extracted from communications between the mobile unit 1102 and the switch 1106. In the case of handset-based location finding equipment such as GPS information, location coordinates may be encoded into communications transmitted from the unit 1102 to the cell site equipment 1104. In other cases, raw location information may be preprocessed by a location management program running on the gateway 1108 or another platform.

In the illustrated embodiment, the gateway 1108 is illustrated as including a location of interest database 1112 and a location cache 1122. Such a database 1112 may include service zone definitions or other locations of interest for one or more of the location-based service applications 1114, 1116 and 1118. The location cache 1122 may include location information for mobile units at various times indexed, for example, to a mobile unit identifier such as a MIN/ESN. Although the database 1112 and cache 1120 are thus illustrated as distinct elements, it will be appreciated that the database 1112 and cache 1120 may utilize shared or non-dedicated memory resources. Moreover, the database 1112 and cache 1120 need not be located on the gateway 1108 or on the same machine as one another, but rather, may reside at any location where the stored information can be accessed by the source selection and location provisioning application.

As noted above, depending on the specific application and other factors, the resulting service information can be transmitted to different recipients via different pathways. For example, in the case of an asset tracking application, the resulting service information may be provided to a data terminal at a monitoring station remote from the monitored mobile unit. To support such applications, service information can be transmitted from the illustrated gateway 1108 to a data network interface 1124 for transmission across a data network such as the Internet. In other applications, such as re-rating for location-based billing applications, the recipient of the service information is another application such as a billing application that is registered with the gateway 1108 to receive service information, e.g., related to mobile unit location at call time. In the case of the location-based billing application, the service information may be a billing value in a Call Detail Record (CDR) 1126. In such a case, the service information may be transmitted to the associated application by way of the switch 1106. In other cases, such as applications that provide information about local services (e.g., hotel locations), it is desirable to transmit the service information to the monitored mobile unit 1102. In such cases, the service information may be transmitted to the unit 1102 via the switch 1106 and cell site equipment 1104.

The location-based service applications 1114, 1116 and 1118 may run on the gateway 1108 or on another platform. In any case, communications between the source selection and location provisioning application and the service applications 1114, 1116 and 1118 may be handled via interface 1113. This interface preferably provides a standardized form, message sets and data fields for transmitting/receiving location requests and receiving/transmitting location information as described in U.S. Patent No. 6,321,092 entitled "Multiple Input Data Management for Wireless Location-Based Applications," which is incorporated herein by reference. Such an interface advantageously allows applications 1114, 1116 and 1118 to operate without compatibility concerns regarding network environment and the nature of the location sources 1127 – 1129.

The service information may be presented in various forms. For example, service information may be transmitted to the mobile unit 1102 via a short messaging system via a data channel or via an audio channel for

providing an audio message that can be played on the unit 1102. In this regard, a text message may be displayed on a LCD display or other display of the mobile unit 1102. As previous noted, an output may be provided to an application 1122 such as a billing application by populating a field of the CDR. In other applications, an audio, text and/or full graphics presentation (e.g., a graphical map showing mobile unit location) may be provided at a data network interface 1124. It will thus be appreciated that the source selection and location provisioning application may utilize appropriate hardware, firmware and/or software for providing the service information in the appropriate format and in accordance with appropriate protocols. Thus, the information may be packetized for transmission across the Internet in accordance with IP protocols. Data may also be transmitted to the mobile unit 1102 utilizing proxies, a microbrowser and other elements for executing a wireless data communications protocol. Similarly, in the case of a CDR output, the CDR may be populated in accordance with telecommunications network protocols.

The gateway 1108 can support multiple location-based services applications, as generally indicated by applications 1114, 1116 and 1118. The present invention supports a number of applications where service information (e.g., routing information, call rating information, local service information, etc.) is provided in response to comparing mobile unit location to stored location information, e.g., a home zone or other service zone or a boundary. A number of examples of such applications are described below. It will be appreciated that many more examples are possible. Nonetheless, the following examples illustrate that such applications can vary, for example, with respect to the types of service information that are generated as well as how and to whom or what the service is reported.

One type of application where it may be desired to monitor boundary crossings relates to fleet management such as rental vehicle tracking. Rental vehicles may be tracked to insure that the tracked rental vehicle is being used in accordance with the rental contract, e.g., that the vehicle is not being taken across certain national borders. Boundary crossings may be proscribed due to insurance limitations, political/social considerations or other reasons. The rental company may therefore desire to receive notification when boundary

crossings occur. It will be appreciated that the rental company would not necessarily require continual updates of vehicle locations (though some companies may choose to obtain such updates) but, most importantly for present purposes, will desire notification triggered by a boundary crossing event.

Such notification can be conveniently provided via a data network such as the Internet. In this manner, an official of the rental company may receive a graphical or text notification identifying the monitored vehicle and the boundary crossing event, e.g., "ID #nnn has crossed into/out of the United States." In response to such notification, the rental company may contact the lessee (e.g., by car phone) remotely disable the rental vehicle, assess a contractual penalty or take other remedial measures.

As will be discussed in more detail below, such a boundary crossing event can be identified using a conventional wireless telephone or other mobile unit carried by the rental vehicle and, preferably, configured to remain powered on when the vehicle is in use. Such a monitoring application can take advantage of existing wireless network gateways and location finding equipment to provide monitoring with minimal, if any, equipment on board the rental vehicle dedicated to position monitoring, thereby reducing costs and facilitating rapid deployment. As described below, a wireless network gateway remotely or locally associated with a network switch can be connected to one or more location finding equipment systems for receiving location information regarding the monitored vehicle or its on-board mobile unit and can be further connected to a data network for providing reports to the rental company's data terminal.

Another type of application where it may be desired to monitor mobile unit location on a one time or repeated basis is call management applications including call routing applications like E911 (which may further involve forwarding location information to a Public Safety Answering Point – PSAP) location-based billing applications. For example, in location-based billing applications, the rate applied for calls placed or received using a wireless telephone depends on the location of the phone. In this regard, wireless carriers may wish to encourage subscribers to more fully use their wireless phones by providing call rating competitive with land line phones for calls

placed in or near the subscriber's home, office or other defined location, but providing a different rating for calls placed or received outside such "home zones." The relevant rating information may be provided to a billing system of the carrier or other service provider by populating an associated field of a Call Detail Record (CDR) with a billing value. In the case of E911 applications, the mobile unit location may be compared to PSAP coverage areas for the purpose of call routing.

In connection with such applications, it may be desired to check mobile unit location at call time and/or monitor boundary crossings independent of call status for a number of reasons. For example, in the case of location-based billing, a location request may be transmitted at call initiation or some other time to determine a rate for the call. Alternatively, crossings into or out of a home zone may be used to re-rate an ongoing call or otherwise re-set a billing parameter. Also, it may be useful to provide an indication to the subscriber regarding location relative to a home zone, e.g., via a display element on the handset, so that the subscriber can know in advance of a call what rates may apply. Thus, boundary crossings may be monitored in order to transmit messages to the mobile unit causing the display element to toggle between "home zone" and "outside home zone" displays. In the case of call re-rating, a single call may be divided into parts billed at different rates, e.g., by generating multiple CDRs, or a single rate may be selected based on a boundary crossing. In either case, the service information provided by the application may simply be a rating value and the recipient may be a billing application.

A final example of applications that may make use of boundary crossing or other location information is a local service or friend notification application. Such an application may provide emergency information - e.g., regarding local traffic, weather, or other emergency conditions - or other service information – e.g., information about local hotels, restaurants or other services – to all or subscribing system users upon entry into a service area. For example, in the case of severe weather warnings, a traveler may be notified by phone or display upon entering the affected area (such as on crossing a county line). For a traffic jam, warnings and alternative route or other information may be provided to commuters coming within a certain area

encompassing the problem location. Similarly, local service providers may transmit pricing, event or other service information to willing, approaching travelers. In the case of "friend" notification, a subscribing system user and/or an identified "friend" may be notified when the user comes within a certain proximity of the mobile unit of the friend or the friend comes within a certain proximity of the user. In such cases, the "boundary" may be defined and redefined "on the fly".

In such cases, service information may be transmitted to the monitored mobile unit, an associated data terminal or other device proximate to the monitored unit. The information may be provided in audio, text, graphical or other form depending, for example, on the limitations of the user equipment and the type of information required. Transmission of the service information may be triggered by crossing a political or government boundary, crossing within a radius of a location of interest or otherwise crossing a service zone boundary of any shape.

As the foregoing examples illustrate, the type of service information, form of service information transmission, intended recipient and other details can vary from application to application or even within a particular application in accordance with the present invention. The illustrated applications 1114, 1116 and 118 may be any of various types of location-based service applications and substantially any number of applications may be supported by the gateway 1108 in accordance with the present invention.

As shown in Figure 17, multiple sources 1126 – 1129 may be associated with the network 100. As shown, these sources may be connected to the gateway via the switch or independent of the switch. These sources may employ any of a variety of location finding technologies including AOA, TDOA such as GPS and cell/sector technologies. It will be appreciated that the nature of the data obtained from the sources 1126 – 1129 as well as the path by which the data is transmitted varies depending on the type of source and the ability to accommodate a variety of sources is an important aspect of the present invention. Some types of sources include equipment in the handset. Examples include certain GPS and other TDOA systems. In such cases, location information may be encoded into signals transmitted from the handset to a cell site or other receiver, and the information may then be

transferred to the gateway 1108 via the switch 1106 or otherwise. Other sources, e.g., network-based systems, use equipment associated with individual cell sites such as specialized antennae to make location determinations such as by triangulation and, again, the resulting location information may be transferred to the gateway 1108 via the switch 1106 or otherwise. Still other sources employ a network of dedicated source equipment that is overlaid relative to the wireless network 1100. Such systems may communicate location information to the gateway 1108 independent of the switch 1106 and network cell site equipment. In addition, some source technologies can be implemented via equipment resident in the handset, in cell sites or other network locations and/or in dedicated sites such that the data pathway of the location information may vary even for a given source technology.

Although a number of the illustrated sources 1126 – 1129 are shown as operating separate from the switch 1100, in reality, certain ones of the sources, such as a cell ID source, would likely provide information via the switch 1106. The sources may further include network-based AOA systems and network-based TDOA systems and external systems such as GPS. Generally, the illustrated network based systems such as AOA and network TDOA systems determine the location of a wireless station 1102 based on communications between the wireless station and the cell site equipment of multiple cell sites. For example, such systems may receive information concerning a directional bearing of the wireless station 1102 or a distance of the wireless station 1102 relative to each of multiple cell sites. Based on such information, the location of the wireless station 1102 can be determined by triangulation or similar geometric/mathematic techniques. External systems such as GPS systems, determine the wireless station location relative to an external system. In the case of GPS systems, the wireless station 1102 is typically provided with a GPS receiver for determining geographic position relative to the GPS satellite constellation or forwarding satellite based information to a network element that computes location. Thus, various types of location information may be transmitted across an air interface to the network 1100. Additionally, in the case of network assisted GPS or A-GPS,

certain GPS information may be combined with network information to compute the location of a mobile unit.

As shown, the gateway 1108 receives location information from the various sources 1126 – 1129. The nature of such information and handling of such information is described in more detail below. Generally, however, such information is processed by the source selection and location provisioning application to provide location outputs for use by any of various service applications 1114, 1116 and 1118 in response to location requests from the application.

Figures. 18 – 20 illustrate the present invention in the context where the service application is a location-based billing application. Referring first to Figure 18, a portion of a wireless network is generally indicated by the reference numeral 1200. As shown, the network 1200 is divided into a number of cells 1202. For purposes of illustration, the cells are illustrated as being regular in terms of size and shape. In reality, the various cells of a wireless network may vary in size and shape due to terrain and other factors. Moreover, the coverage areas of the cells may overlap to a significant extent such that a mobile unit located at a particular location may communicate via any one of two or more adjacent cell site antennas. Finally, although Figure 18 illustrates undivided cell areas, a given cell may be divided into sectors, e.g., three approximately 1120 ° areas relative to a center point of a cell. In this regard, cell sector information may be available to better determine the approximate location of a mobile unit. Thus, although Figure 18 illustrates a simplified topology of a wireless network, it should be appreciated that various types of network typology information may be utilized to locate a mobile unit in accordance with the present invention.

In the illustrated network 1200, a subscriber's home zone 1204 is defined as a circular area surrounding a home zone location, e.g., geographical coordinates defining the subscriber's residence, work location or other specified location. It will be appreciated that the home zone 1204 may be of any shape and need not be centered relative to a residence or the like. As shown, the home zone 1204 overlaps three adjacent cells designated cells C, D and E. In a typical location-based billing application, the subscriber will be charged a first rate, such as a rate competitive with land line rates, for calls

within the home zone 1204, and a second rate, such as the normal rate for wireless network usage under the subscriber's plan for calls outside of the zone 1204.

Ray 1206 illustrates the travel path of a moving mobile unit. As shown, the unit travels from cell A through cell B and cell D towards home zone 1204. In the examples below, the user is assumed to place a succession of calls during travel along this pathway 1206 and the system of the present invention is utilized to efficiently obtain location information from a cell ID source and a multilateration source such as a TDOA or GPS source.

This process is illustrated in the flow chart of Figure 19. The process 1300 is initiated by storing (1302) a location of interest. This could be stored, for example, at a gateway platform, application platform or other network element. The nature of this location information can vary depending, for example, on the type of location-based service application and the specific implementation. For example, in the case of the illustrated location-based billing application, the home zone information may be defined relative to a particular subscriber's residence or based on predefined service zones. In the former case, the home zone may be defined as a circle of predefined radius centered at the subscriber's residence location. In the latter case, home zones may be defined by zip codes, street boundaries or other predefined zones. For other applications, the location information need not define an enclosed area but may involve a single boundary or any other type of appropriate location information. As noted above, the home zone may be defined by reference to a quadtree data structure.

After the location of interest has been stored, a gateway, service application or other system in accordance with the present invention may receive (1304) a location request. In the case of a gateway associated with a location-based billing application, the location request may be received from the service application upon receiving an indication that a subscriber has placed or received a call. Alternatively, such an application may request ongoing monitoring of subscriber location, for example, to continually provide an indication to a subscriber regarding zone status. Thus, the location request may be a one time only request or an ongoing update request.

In the illustrated implementation of the present invention, cell ID information is used for monitoring so that instances of invoking a relatively high resource position determination system such as a multilateration source can be minimized for enhanced efficiency. Accordingly, the illustrated process 1300 initially proceeds by accessing (1306) a cell ID source. It will be appreciated that cell ID information is encoded into standard telecommunications network messages for the purposes of call routing. Accordingly, such information is readily available, for example, from an HLR or switch. Moreover, if the location gateway is implemented in connection with a platform for managing other network functions related to network management, such information may be immediately available on the platform where the gateway is implemented. In any case, such cell ID information can generally be obtained with minimal use of resources and minimal response time as such information generally resides within the network.

In a preferred implementation of the present invention, the cell ID location is next converted (1308) into geographic coordinates, e.g., a circular area circumscribing the geographic coverage area of the corresponding cell. Such translation facilitates efficient location comparisons. Thus, for example, both the home zone definition and the cell location definitions may be expressed in terms of geographical coordinates and then mapped to a quadtree data structure representing the area of the network. The quadtree data structure can then be used as described in U.S. Patent No. Patent No. 6,212,392, noted above, to make efficient location comparisons. Moreover, by processing home zone definitions and cell definitions in terms of geographical coordinates, or quadtree elements, rather than in terms of cell ID information, the need for database revision is reduced in relation to changing network topology.

The cell ID information can then be compared (1310) to the location of interest. In the case of location-based billing applications, this comparison is generally made to determine if the mobile unit is inside or outside of the location of interest. In other applications, such as boundary crossing applications, the cell unit location may be compared to a boundary line or another locus of points to determine information regarding proximity to the location of interest. If no match is found between the mobile unit location and

the stored location of interest, an "out of home zone" message is reported (1314) to the service application. In response to this message, an appropriate rate for the call may be applied and/or a corresponding display element may be provided on the subscriber's handset.

In the case of the illustrated location-based billing application, if the comparison of the cell ID of the mobile unit matches (1312) the location of interest, then a more accurate location source may be invoked. This may be understood by reference to Figure 18. If a call is placed by the mobile unit at a point on path 1206 within cell D (or cell C or cell E), the cell ID information alone is insufficient to determine whether the call is placed inside or outside of home zone 204. An application may simply give the subscriber the "benefit of the doubt" and consider any call placed anywhere within cells C, D and E as being placed within the home zone. However, such an implementation would effectively enlarge the home zone and reduce the service provider's revenues. Moreover, due to irregularities in network coverage, such an implementation may result in different subscribers having substantially different size home zones or an individual subscriber having their effective home zone changed in size due to changes in network topology.

The present invention efficiently allows for a better home zone determination. Thus, when a match is indicated between the cell ID information and the location of interest, the illustrated method proceeds to invoke (1316) a second source such as a multilateration source, for example, to obtain more accurate location information. The resulting information is compared to the home zone definition to determine whether there is a match (1318). Thus, for example, it may be determined that at the time of a call the mobile unit is within cell D but outside of home zone 1204. Alternatively, the information from the second source may indicate that the call is being placed from within the home zone. If it is determined that the call is from outside of the home zone, then an "out of home zone" message is reported (1314) to the location-based billing application. For example, a predefined field of a call detail record may be populated with one or more bits of information indicating a rating value. The location-based billing application uses this information for rating the call and may also provide an indication of zone status to the subscriber via a display of the mobile unit. Additionally, the mobile unit

location may be utilized to determine a timing for a subsequent source invocation. For example, if the mobile unit is far from the subscriber's home zone, it may be determined that no further location update is required for a period of time determined based on distance and assumed or known travel speeds. On the other hand, if the call is placed from inside of the home zone, an "in home zone" message is reported (1320) to the location of a billing application and this information may be used for rating purposes and may be reported to the mobile unit. In either case, the location of a billing application applies (1322) the appropriate billing parameter for the call. Depending on the application, the method 1300 may further involve continuing to monitor (1324) the location of the mobile unit, for example, to provide an ongoing indication of the zone status.

Figure 20 is a message flow diagram corresponding to a series of phone calls placed by the subscriber along travel path 1206 of Figure 20. The columns of the diagram correspond to the network nodes associated with the service application, the gateway, the associated processor, and the at least two location sources. The rows of the array are ordered in time sequence corresponding to the message flow. Thus, at a first time corresponding to a first point along path 1206, the application transmits a request (1400) to the gateway for location information, for example in response to a call initiation by the subscriber. The gateway then accesses (1402) source 1 which is a cell ID source. The source returns information (1404) indicating that the subscriber is located in cell A. This information is transmitted (1406) to the processor which compares the cell ID location to the home zone definition. As discussed above, this comparison may be performed in terms of geographical coordinates or quadtree data elements rather than in terms of cell ID information. In this case, the processor indicates (1408) that the cell ID location does not match the home zone definition. For example the logic for making this determination may recognize that no point within cell A is also within the home zone, i.e., there is no overlap. This is then reported (1410) by the gateway to the application. The application may use this information to assign a rate for the call and/or to report zone status to the subscriber.

Subsequently, the application may transmit another location request (1412) to the gateway. It should be appreciated that, although the example of

Figure 20 relates to a succession of one time only location requests, a similar series of location comparisons may be implemented in connection with a location request that requests periodic or other repeating location updates. In such a case, the illustrated message sequence would change slightly related to messages between the application and gateway. In any case, in response to the second location request of Figure 20, the gateway again accesses (1414) to obtain cell ID information (1416) indicating that the call is being placed from cell B. This information is reported (1418) to the processor which again performs a comparison and determines that there is no match between the cell ID location and the home zone. This information is once again reported (1420) to the gateway and, in turn (1421) to the application.

Thereafter, a third location request (1422) is transmitted from the application to the gateway. Once again, in response to this location request, source 1 is accessed (1424) to obtain cell ID information. Source 1 responds (1426) by indicating that the mobile unit is located within cell B. This information is reported (1428) to the processor to perform a comparison of the cell ID information to the home zone definition. In this case, the comparison indicates (1430) a match, that is, an overlap between the definition of cell D and the home zone definition. It will be appreciated that this comparison is not necessarily determinative as to the true position of the mobile unit relative to the home zone. Accordingly, the gateway invokes (1432) source 2 to provide location information. The nature and accuracy of the location information reported back (1432) from the second source depends on the nature of the source. In the case of a multilateration technology, such information may include geographical coordinates coupled with an uncertainty. It will be appreciated that this location information defines an area, albeit an area smaller than a cell coverage area. This coordinate information is passed (1436) to the processor which again performs a comparison to determine any overlap between this more accurate location information and the cell definition. This comparison may be performed in terms of an overlap determination as between the quadtree elements corresponding to the uncertainty region of the location information and the quadtree elements corresponding to the home zone definition. In this case, the processor determines (1438) that there is no match. That is, although the

mobile unit is located within cell B, it is outside of the home zone 1204. This is reported (1440) to the application.

Finally, the application transmits a fourth location request (1442) to the gateway. In response to this request, the gateway requests (1444) cell ID information from source 1. Source 1 responds (1446) with information indicating that the mobile unit is located in cell D. This information is reported (1448) to the processor which reports (1450) a match in that cell D overlaps with the home zone. In response to this initial match, the gateway invokes (1452) source 2 to provide more accurate location information. Source 2 responds (1454) with location information, e.g., in terms of geographical coordinates and an uncertainty radius defining an uncertainty region. This is reported (1456) to the processor which performs a further comparison and, in this case, determines (1458) that there is a match. That is, the location or uncertainty area associated with the more accurate location information overlaps with the home zone 1204. This match is then reported (1460) to the service application. In this manner, the benefits of using a more accurate source of location information can be achieved without unnecessarily invoking such a source when lower resource or a faster response time information yields sufficient information for the purposes of the application under consideration.

In the example of Figure 20, the various determinations as to whether the mobile unit was located inside or outside of its home zone were performed by a processor separate from the application platform, e.g., associated with the gateway. In some cases, it may be desired to execute such logic in connection with the application. For example, in the context of a location-based billing application, a single subscriber may have multiple defined zones, e.g., a home zone, a work zone, a school zone, etc. It may be more convenient for the application to make comparisons relative to these multiple zones. Additionally, as will be understood from the following description, executing such logic in conjunction with the application platform may reduce the number of messages transmitted across the gateway interface thereby further conserving valuable resources.

Figure 21 illustrates a message sequence where the zone comparison logic is executed at the application platform. In particular, Figure 21 illustrates

a message set where first and second sources are sequentially accessed analogous to messages 1442 – 1460 of Figure 20. It will be appreciated that, in the context of the present invention, it may only be necessary to access one of the sources in order to obtain adequate information for a zone comparison as discussed above.

The illustrated message sequence is initiated when the application transmits a message (1542) to the gateway seeking location information for an identified mobile unit. This location request may explicitly request location information from a particular source, such as a low resource source like cell ID, or may otherwise specify a low quality of service parameter. In response to this request, the gateway invokes (1544) source 1 and obtains location information (1546), in this case, cell ID information. This information is reported (1548) to the application which compares the location information to one or more defined zones of the subscriber. As discussed above, it may be possible to establish conclusively based on the cell ID information that the subscriber is within or outside of one or more zones of interest. In the illustrated example, it is assumed that the cell ID information is inconclusive. Accordingly, a further location request (1550) is transmitted from the application to the gateway. Again, this location request may explicitly identify source 2 or may otherwise specify a more stringent quality and service with regards to the accuracy of the requested location information. In response to this request, the gateway invokes (1552) source 2. Source 2 responds with location information (1554) such as location coordinate information based on a TDOA or other location technology. This information is then reported (1556) to the application such that an in zone or out of the zone determination can be made. It will be appreciated that architectures other than those shown in Figures 20 and 21 may be implemented for making location comparisons in connection with other network elements.

The foregoing description of the present invention has been presented for purposes of illustration and description. Furthermore, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, and skill and knowledge of the relevant art, are within the scope of the present invention as defined by the following claims.

What is claimed:

1. A method for providing location information regarding a mobile communications unit of a mobile communications system, wherein a mobile communications unit location information management system utilizes a plurality of position determination equipment sites, wherein said method comprises the steps of:

executing a first determining step comprising determining at least a general location of a first said mobile communications unit;

executing a second determining step comprising determining if any of said plurality of position determination equipment sites are able to provide location information on said first said mobile communications unit based upon said general location from said executing a first determining step.

2. A method, as claimed in Claim 1, wherein:

said mobile communications system further comprises a plurality of cells which each encompass a predetermined area, wherein said executing a first determining step comprises identifying said cell in which said first said mobile communications unit is physically located.

3. A method, as claimed in Claim 1, wherein:

said executing a first determining step comprises consulting a mobile communications unit database, wherein a most recent known location of said first said mobile communications unit is stored in said mobile communications unit database, along with a time associated with said most recent known location for said first said mobile communications unit.

4. A method, as claimed in Claim 1, wherein:

said executing a first determining step is executed other than through any of said plurality of position determination equipment sites.

5. A method, as claimed in Claim 1, wherein:

said executing a second determining step comprises consulting a database in which information on said plurality of position determination equipment sites is stored.

6. A method, as claimed in Claim 1, wherein:

information on said plurality of position determination equipment sites is stored in a database, wherein said information comprises an identifier and a coverage area for each said position determination equipment site, and wherein said executing a second determining step comprises comparing said general location of said first said mobile communications unit with said coverage area of at least one of said position determination equipment sites that is included in said database.

7. A method, as claimed Claim 1, further comprising the step(s) of:

invoking a request for said location information on said first said mobile communications unit to at least one of said position determination equipment sites identified by said executing a second determining step, wherein said invoking a request step is executed only if said at least one of said position determination equipment sites is first identified by said executing a second determining step.

8. A method, as claimed in Claim 1, further comprising the step(s) of:

directing a request for said location information on said first said mobile communications unit toward a mobile communications unit location information management system.

9. A method, as claimed in Claim 1, further comprising the step(s) of:

providing said location information on said first said mobile communications unit from at least one of said position determination equipment sites identified from said executing a second determining step.

10. A method, as claimed in Claim 1, further comprising the step(s) of:

deriving said location information on said first said mobile communications unit using each said position determination equipment site identified from said executing a second determining step.

11. A method, as claimed in Claim 1, wherein:

said executing a first determining step comprises identifying a cell in which said first said mobile communications unit is currently located, and wherein said executing a second determining step comprises retrieving all said position determination equipment sites that are currently associated with said cell in said location information management system.

12. A method for use in providing location information regarding mobile units in a mobile communications system, said method comprising the steps of:

receiving a request for location information for a first Mobile unit, said request identifying said first mobile unit and further including at least a first specification regarding a quality of said requested location information;

based on said first specification, selecting at least one location information source capable of providing responsive location information for said first mobile unit;

obtaining said responsive location information from said selected location information source, wherein said responsive information at least substantially conforms to said first specification regarding said quality of said requested location information; and

providing said responsive location information to a selected location based on said request.

13. The method of Claim 12, further comprising the steps of:

receiving a first indication of the general location of said first mobile unit; and

using said general location of said first mobile unit in said selecting step to identify location information sources in a proximity of said mobile unit such that one of said identified location information sources may provide said responsive location information.

14. The method of Claim 12, wherein said step of selecting further comprises selecting at least one location information source from a plurality of

location information sources operable to provide said responsive location information.

15. The method of Claim 14, wherein said plurality of location information sources comprises one of a database containing responsive location information and equipment associated with the mobile communications system operable to obtain responsive location information.

16. The method of Claim 12, wherein said step of obtaining further comprises invoking said selected location information source to provide said responsive location information.

17. The method of Claim 12, wherein:

said specification regarding a quality of said requested location information is related to a geographical accuracy for said responsive location information.

18. The method of Claim 12, wherein said receiving step further comprises correlating said specification to a corresponding value associated with said location information sources.

19. The method of Claim 12, wherein said selecting step further comprises consulting at least a first database in which information regarding location determining abilities of said position location information sources are stored such that only location information sources capable of providing said responsive location information are selected.

20. A method for use in providing location information regarding mobile units in a mobile communications system, said method comprising the steps:

establishing an interface allowing an application to provide requests for location information regarding a first mobile unit from a location platform, said interface defining a number of information fields that may be included in said requests;

receiving a first request for location information at said platform via said interface, wherein said first request includes at least one specification regarding a quality of said requested location information, said specification being included in one of said information fields;

based on said specification, obtaining responsive location information regarding said first mobile unit; and

providing said responsive location information to a selected location based on said request.

21. The method of Claim 20, wherein said step of establishing an interface comprises defining a number of messages that are useable by a user to selectively request location information for said mobile unit.

22. The method of Claim 20, wherein said plurality of information fields includes a field for use in specifying at least one of a priority of said request, a geographical accuracy of said location information, a cost associated with said location information, an age of said information and a response time for said location information.

23. The method of Claim 20, wherein said step of obtaining comprises identifying at least first and second information sources operable to provide responsive location information.

24. The method of Claim 20, wherein said step of obtaining includes accessing at least a first database to correlate capabilities of location information sources in the mobile communications system with said specification.

25. A method for use in providing location information regarding mobile units in a telecommunications network, comprising the steps of:

first obtaining identification information regarding a mobile unit to be located and parameter information regarding the desired location information;

second obtaining first location information regarding said mobile unit from a first source, said first source being associated with a first expected lag

time relating to providing the first location information and a first expected resource requirement related to system resources involved in providing the first location information;

performing a comparison of the first location information to the parameter information;

based on said comparison, selectively obtaining second location information regarding said mobile unit from a second source different than said first source, said second source being associated with a second expected lag time relating to providing the second location information and a second expected resource requirement related to system resources involved in providing the second location information;

where at least one of the first expected lag time and first expected resource requirement is greater than at least one of the second expected lag time and second expected resource requirement; and

providing an output related to said location request based on at least one of said first location information and said second location information.

26. A method as set forth in Claim 25, wherein said step of performing a comparison comprises using said parameter information to define a condition to be evaluated with respect to the desired location information and making a determination as to whether said first location information is sufficient to evaluate said condition.

27. A method as set forth in Claim 25, wherein said step of selectively obtaining comprises invoking said second source to provide said second location information, where said second location information has a location accuracy greater than said first information.

28. A method as set forth in Claim 25, wherein said step of providing an output comprises outputting a rating value for use in billing a call associated with said mobile unit.

29. A method as set forth in Claim 25, wherein said first source is a Cell ID source and said second source is one of a network based location determination equipment source and a GPS source.

30. A method as set forth in Claim 25, further comprising the step of repeatedly invoking said first source prior to said step of selectively obtaining second location information.

31. A method for use in providing location information regarding mobile units in a telecommunications network, comprising the steps of:

obtaining identification information regarding a mobile unit to be located and parameter information regarding the desired location information;

monitoring information from at least a first source over time to obtain successive instances of first location information regarding said mobile unit;

performing a comparison to determine whether a location of said mobile unit as indicated by said monitored information satisfies a defined relationship relative to stored location information;

based on said comparison, selectively obtaining second location information regarding said mobile unit from at least a second source different than said first source; and

providing an output related to said location request based on said second location information.

32. A method for use in providing location information for mobile units in a wireless network, comprising the steps of:

receiving first information regarding a location of interest for a first mobile unit;

receiving a first indication of a location of said first mobile unit at a first time; and

based on said first information regarding said location of interest and said first indication regarding said first location of said first mobile unit at said first time, determining a timing for obtaining a second indication of a second location of said first mobile unit.

33. A method as set forth in Claim 32, wherein said step of determining a timing comprises determining a length of time to wait before obtaining said second information based on a distance between said location of interest and said first location.

34. A method for use in providing location information regarding mobile units in a telecommunications network, comprising the steps of:

providing an interface for use in obtaining location information from a first source and a second source, said first source having a first quality of service characteristic and said second source having a second quality of service characteristic;

determining a required quality of service for a first location operation to locate a first mobile unit; and

based on said required quality of service, using said interface to obtain said location information from said selected one of said first and second sources.

35. A method as set forth in Claim 34, wherein said step of determining comprises obtaining initial location information from said first source having said first quality of service and determining that said first quality of service is insufficient for said first location operation.

36. A method as set forth in Claim 34, wherein said step of determining comprises identifying said first operation as being one of a primary monitoring operation for obtaining general location information or a secondary locating operation, responsive to said primary monitoring operation, for obtaining specific location information.

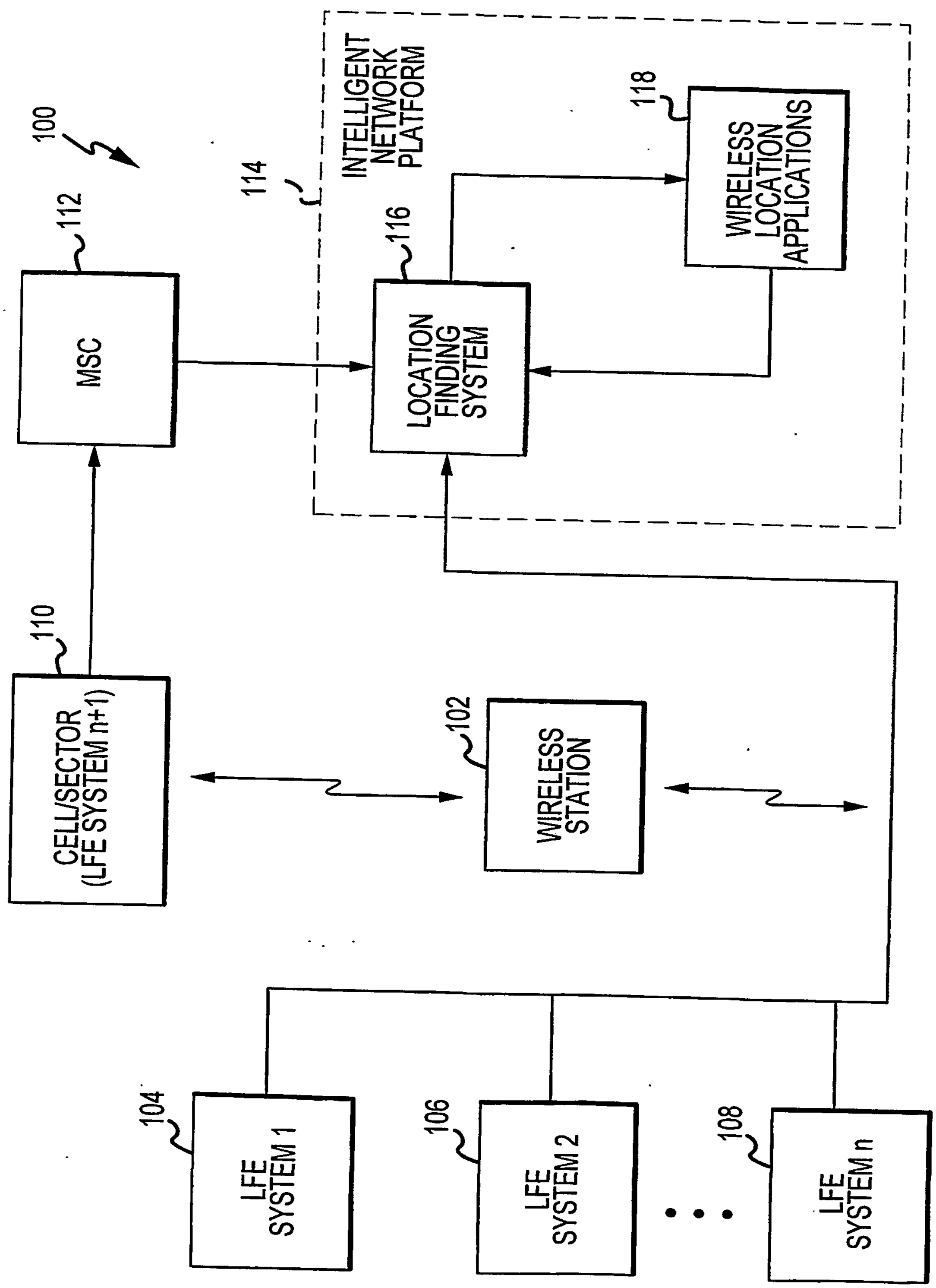

100
MSC
112
INTELLIGENT NETWORK PLATFORM
114
LOCATION FINDING SYSTEM
116
WIRELESS LOCATION APPLICATIONS
118
CELL/SECTOR (LFE SYSTEM n+1)
110
WIRELESS STATION
102
LFE SYSTEM 1
104
LFE SYSTEM 2
106
LFE SYSTEM n
108

FIG.1

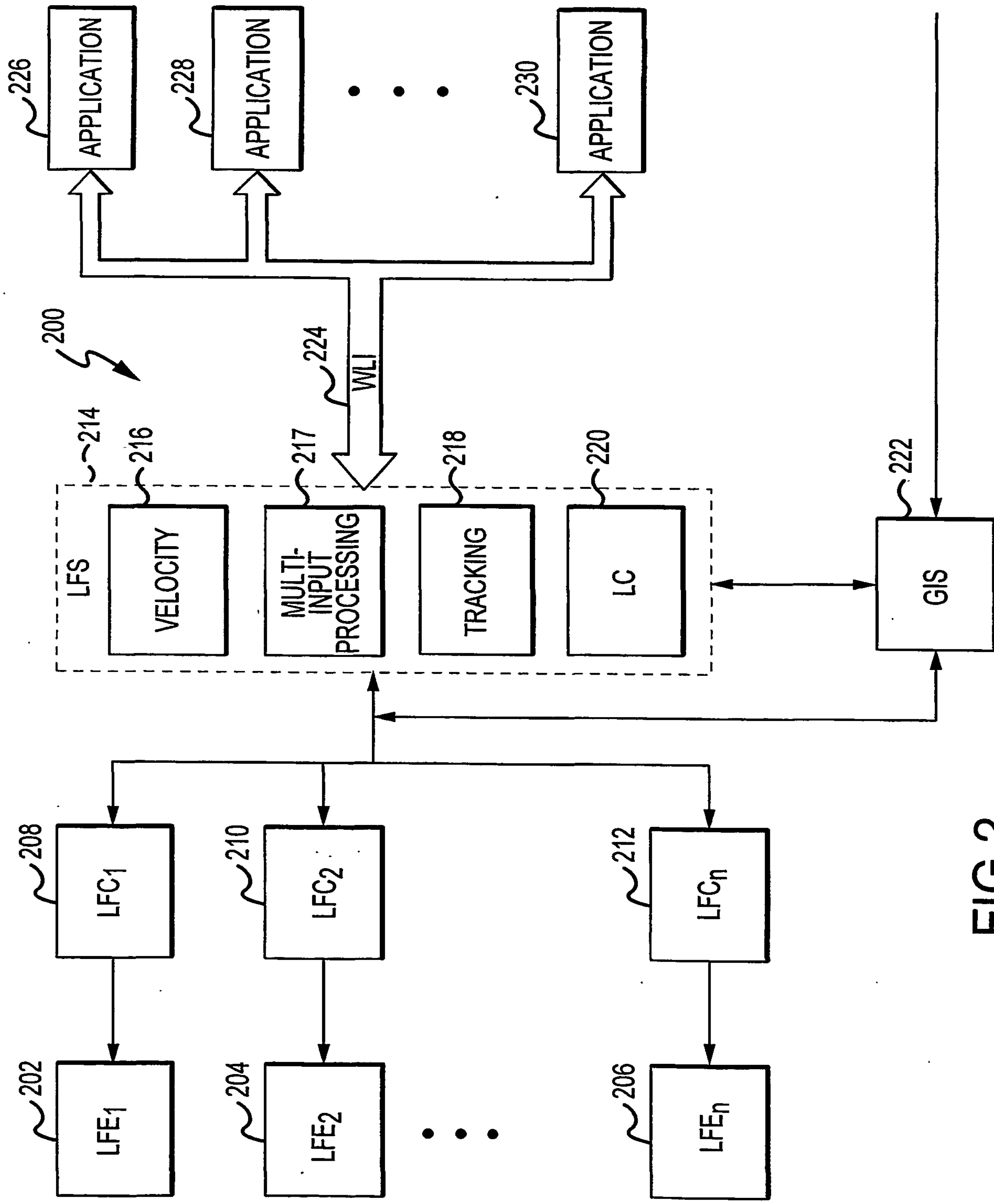

200
226
APPLICATION
228
APPLICATION
230
APPLICATION
224
WLI
214
LFS
216
VELOCITY
217
MULTI-INPUT PROCESSING
218
TRACKING
220
LC
222
GIS
208
$LFC_1$
210
$LFC_2$
212
$LFC_n$
202
$LFE_1$
204
$LFE_2$
206
$LFE_n$

FIG.2

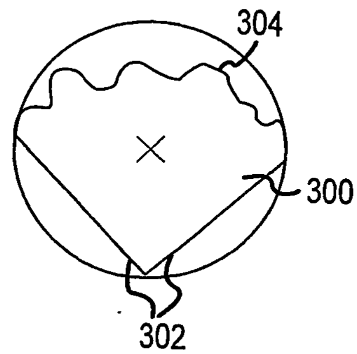



FIG.3A

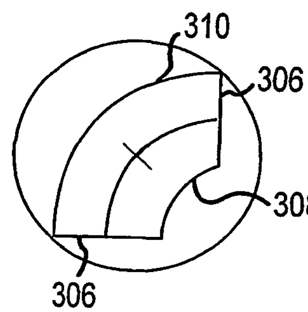



FIG.3B

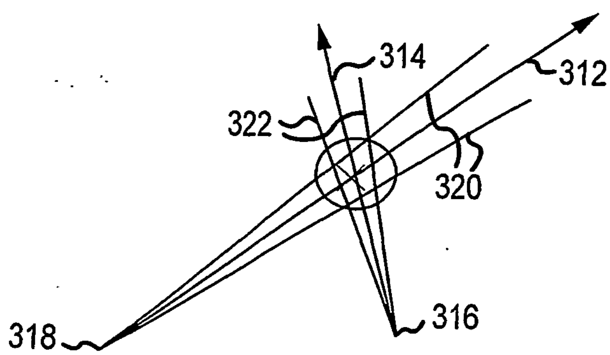



FIG.3C

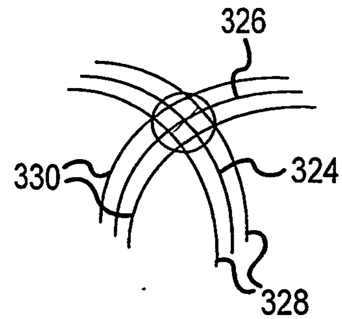



FIG.3D

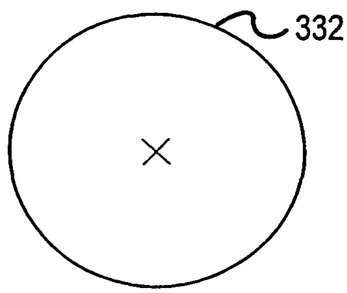



FIG.3E

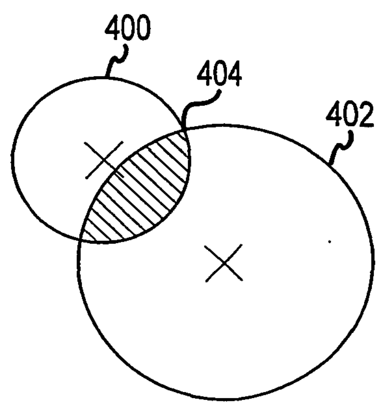



FIG.4

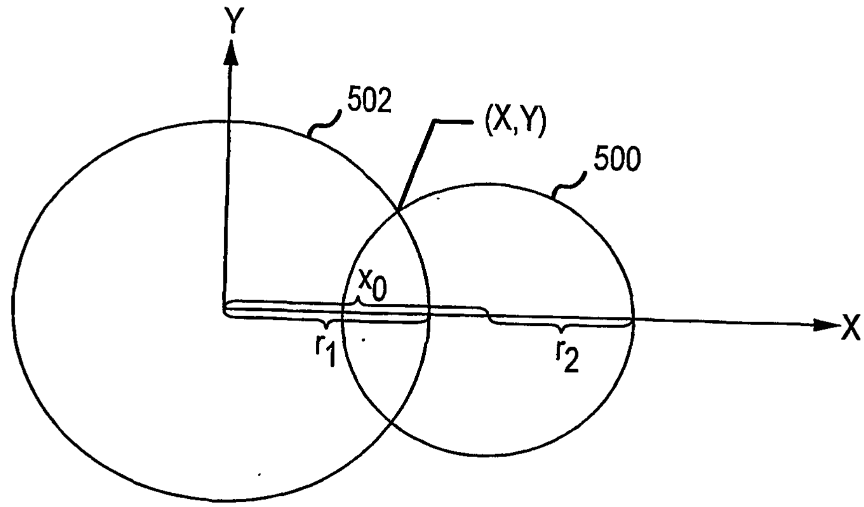

Y
502
(X,Y)
500
$x_0$
X
$r_1$
$r_2$

FIG.5

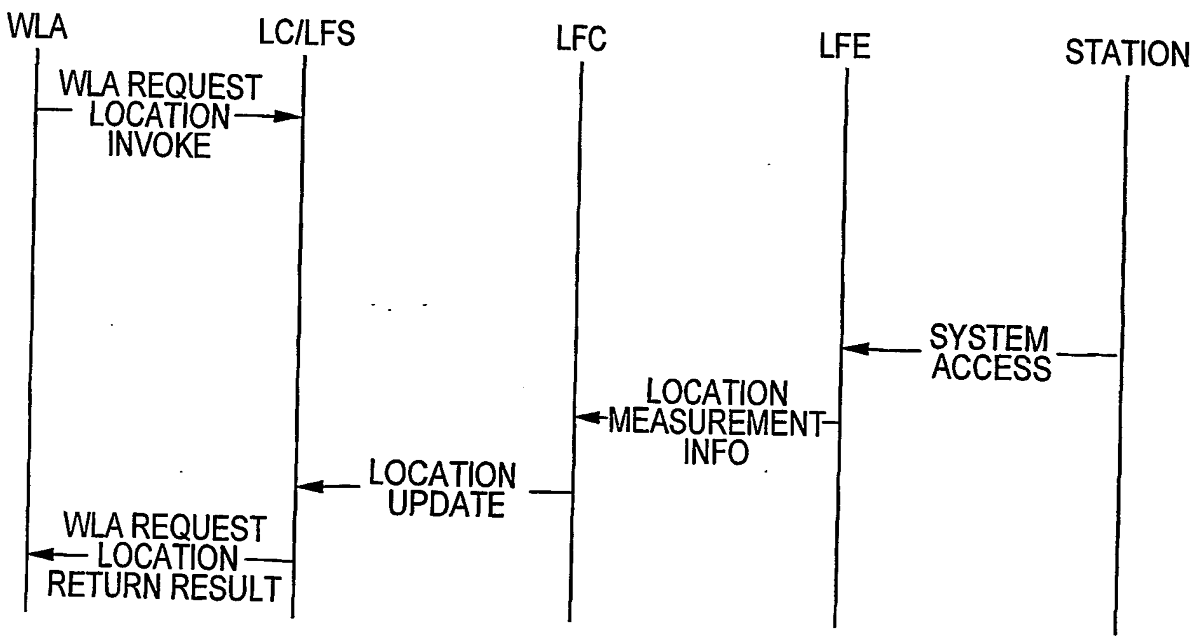

WLA
LC/LFS
LFC
LFE
STATION
WLA REQUEST LOCATION INVOKE
SYSTEM ACCESS
LOCATION MEASUREMENT INFO
LOCATION UPDATE
WLA REQUEST LOCATION RETURN RESULT

FIG.6

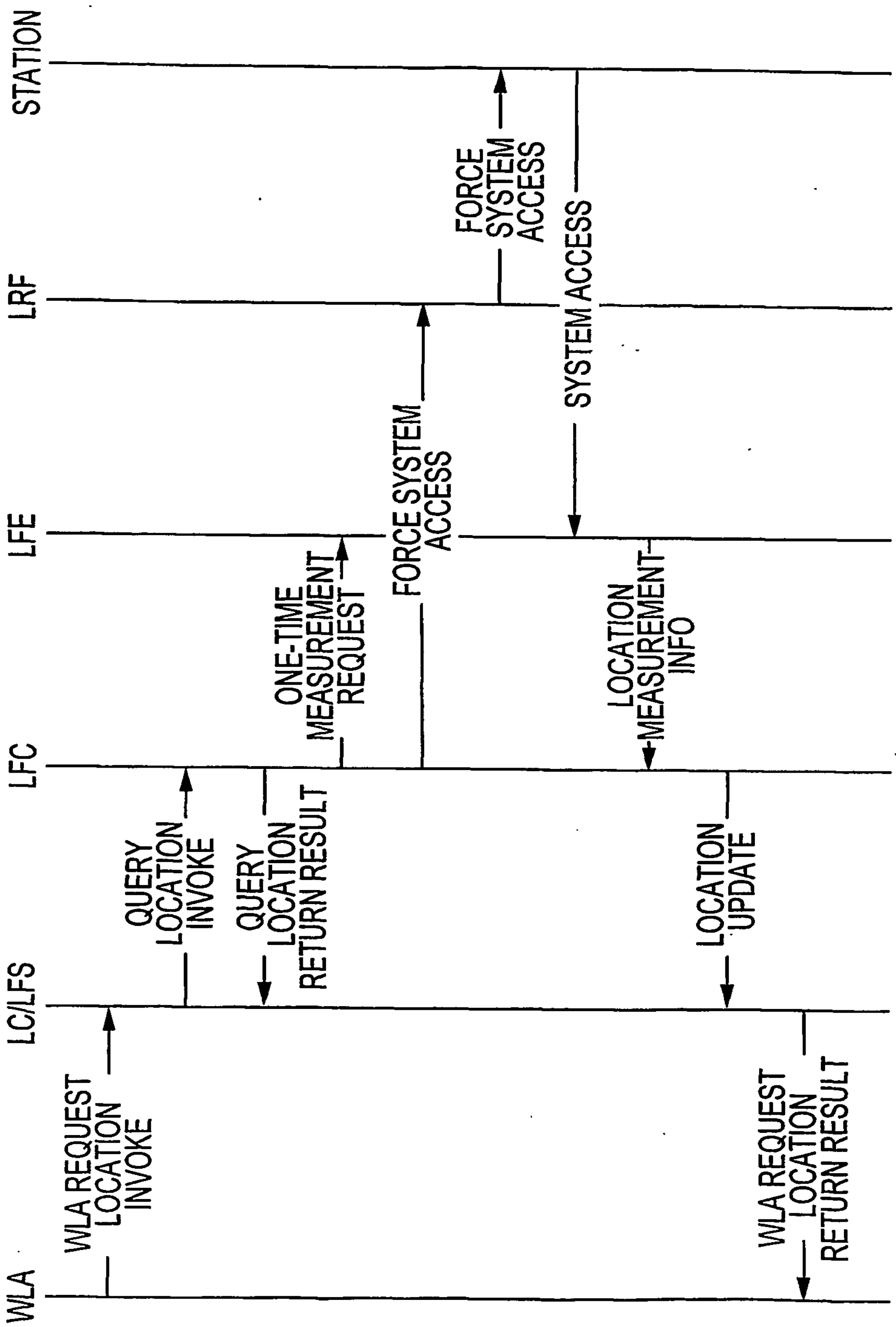

WLA
LC/LFS
LFC
LFE
LRF
STATION
WLA REQUEST LOCATION INVOKE
QUERY LOCATION INVOKE
QUERY LOCATION RETURN RESULT
ONE-TIME MEASUREMENT REQUEST
FORCE SYSTEM ACCESS
FORCE SYSTEM ACCESS
SYSTEM ACCESS
LOCATION MEASUREMENT INFO
LOCATION UPDATE
WLA REQUEST LOCATION RETURN RESULT

FIG.7

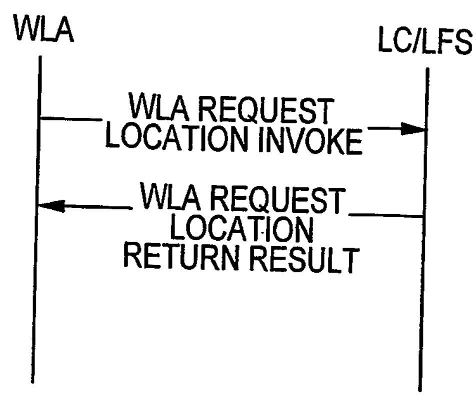

WLA
LC/LFS
WLA REQUEST LOCATION INVOKE
WLA REQUEST LOCATION RETURN RESULT

FIG.8

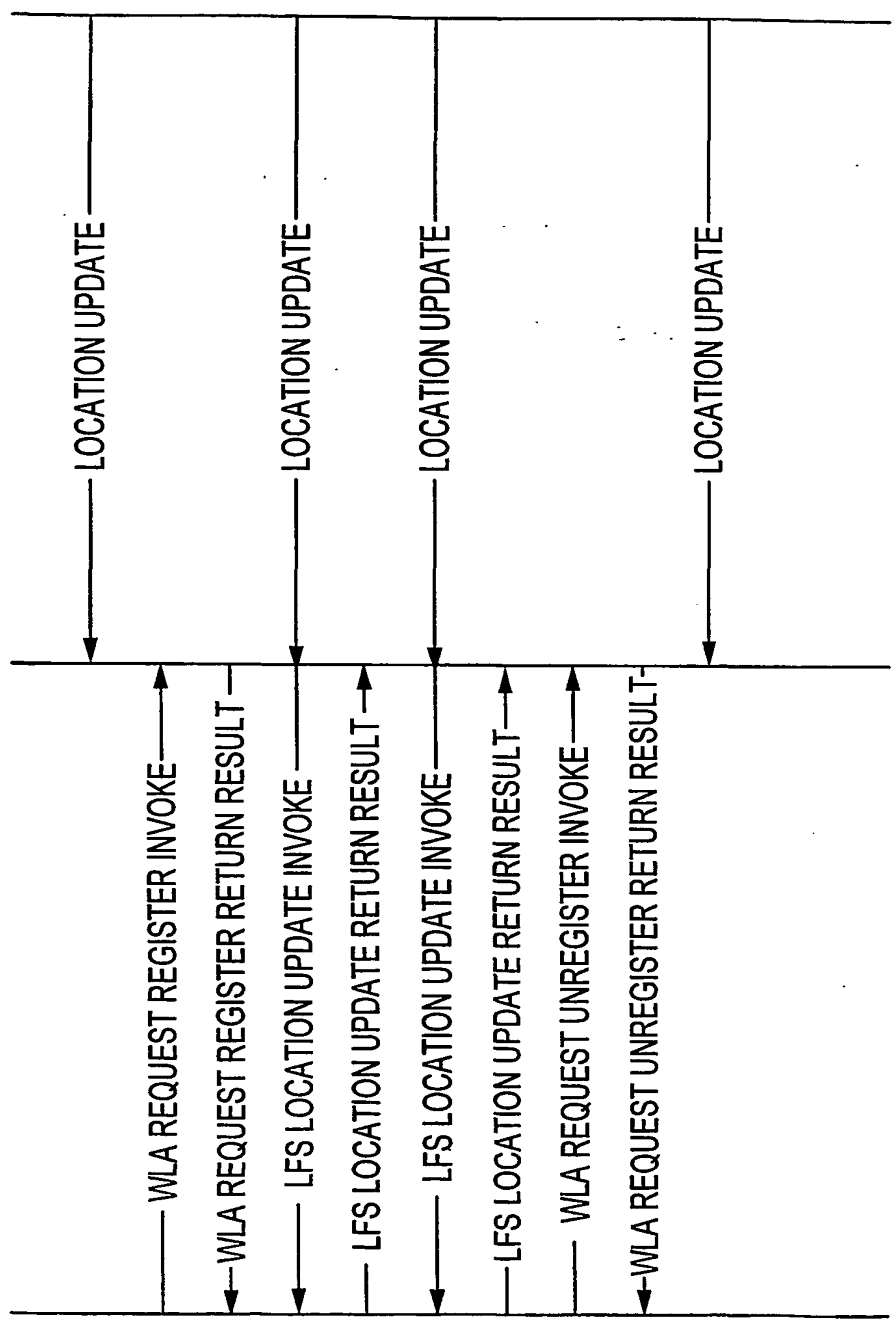

LOCATION UPDATE
LOCATION UPDATE
LOCATION UPDATE
LOCATION UPDATE
WLA REQUEST REGISTER INVOKE
WLA REQUEST REGISTER RETURN RESULT
LFS LOCATION UPDATE INVOKE
LFS LOCATION UPDATE RETURN RESULT
LFS LOCATION UPDATE INVOKE
LFS LOCATION UPDATE RETURN RESULT
WLA REQUEST UNREGISTER INVOKE
WLA REQUEST UNREGISTER RETURN RESULT

FIG.9

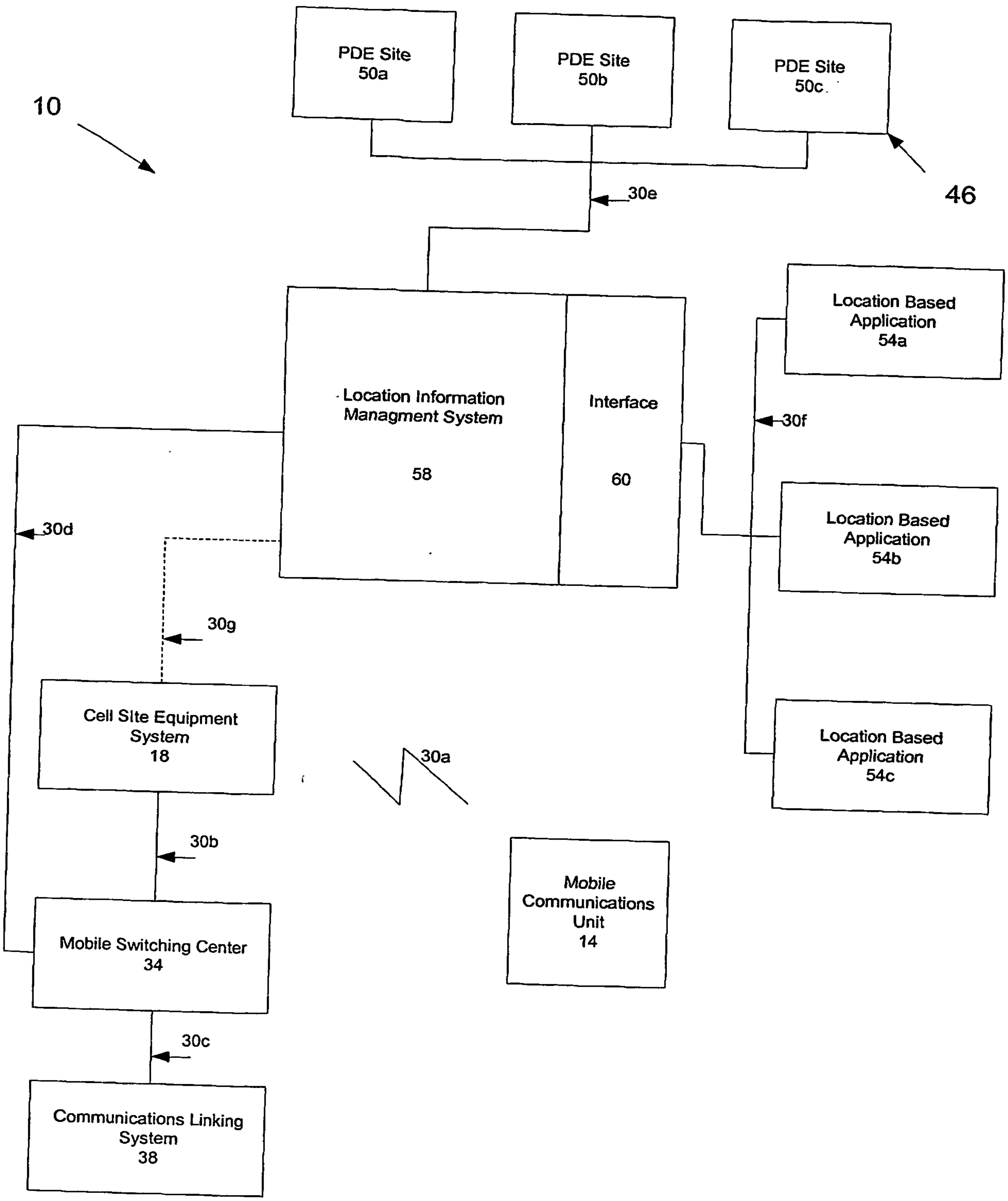

PDE Site
50a
PDE Site
50b
PDE Site
50c
10
46
30e
Location Based
Application
54a
Location Information
Managment System
58
Interface
60
30f
30d
Location Based
Application
54b
30g
Cell Site Equipment
System
18
30a
Location Based
Application
54c
30b
Mobile
Communications
Unit
14
Mobile Switching Center
34
30c
Communications Linking
System
38

FIGURE 10

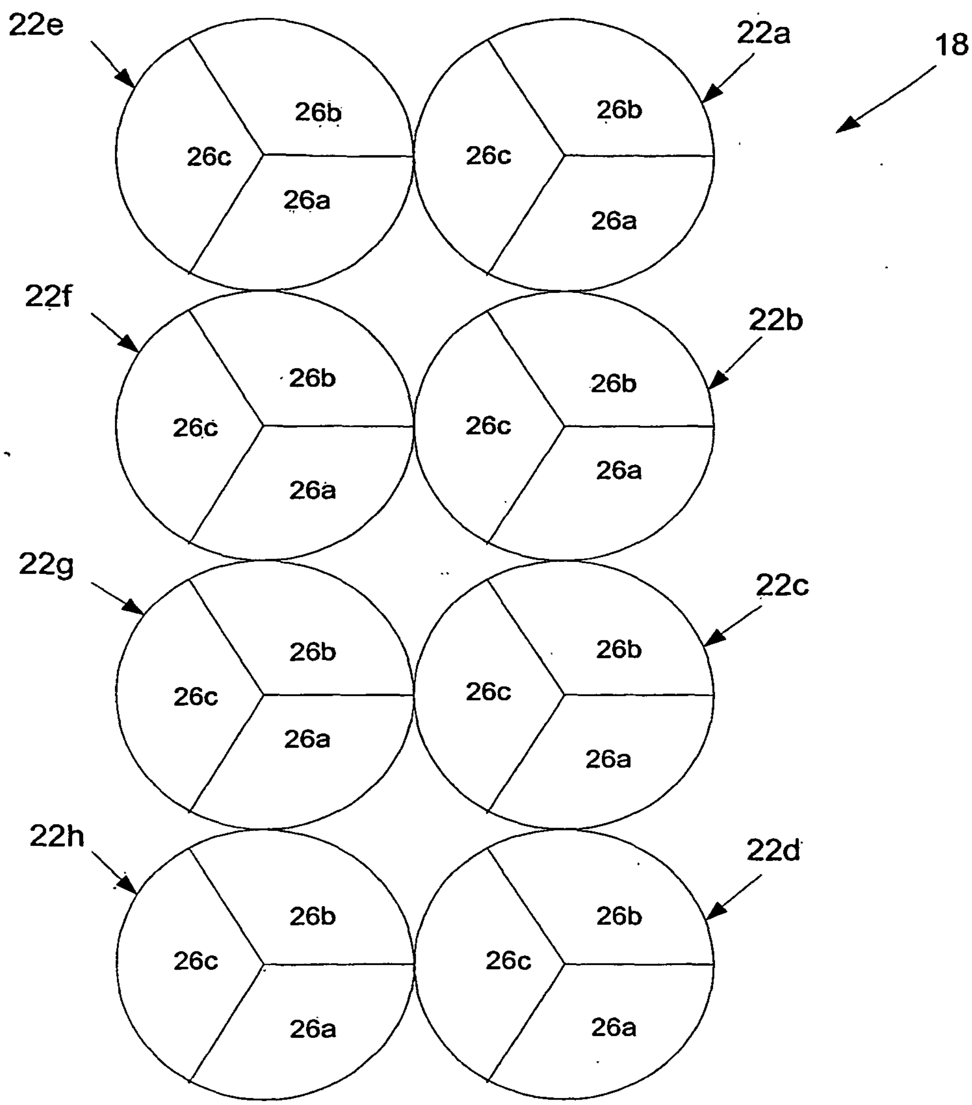



FIGURE 11

Figure 12. PDE site Database 62

| Record | PDE Site 70 | PDE Type 74 | Physical Location 78 | Coverage Area 82 | Determining Accuracy 86 | Computational Speed 90 | Cost 94 | Handset Based 96 | Extra 98 |
|---|---|---|---|---|---|---|---|---|---|
| 66a | | | | | | | | | |
| 66b | | | | | | | | | |
| 66c | | | | | | | | | |
| 66d | | | | | | | | | |

Figure 13 Cell/PDE Database 72

| Cell/ Cell Sector 77 | Available PDE Sites 70a | Available PDE Sites 70b | Available PDE Sites 70n |
|---|---|---|---|
| 75a | | | |
| 75b | | | |
| 75c | | | |
| 75d | | | |

Figure 14 HLR Database 130

| Record | Mobile Unit 138 | Subscriber Address 136 | Subscriber Name 132 | PDE Capabilities 140 | Physical Location Info 144 | Physical Location Time 148 |
|---|---|---|---|---|---|---|
| 104a | | | | | | |
| 104b | | | | | | |
| 104c | | | | | | |

Figure 15 System/PDE Capabilities 160

| PDE Type 164 | Average Determination Accuracy 166 | Average Response Time 170 | Average Cost 172 | 'N' Attributes 174 |
|---|---|---|---|---|
| PDE Type 1 | | | | |
| PDE Type 2 | | | | |
| PDE Type N | | | | |

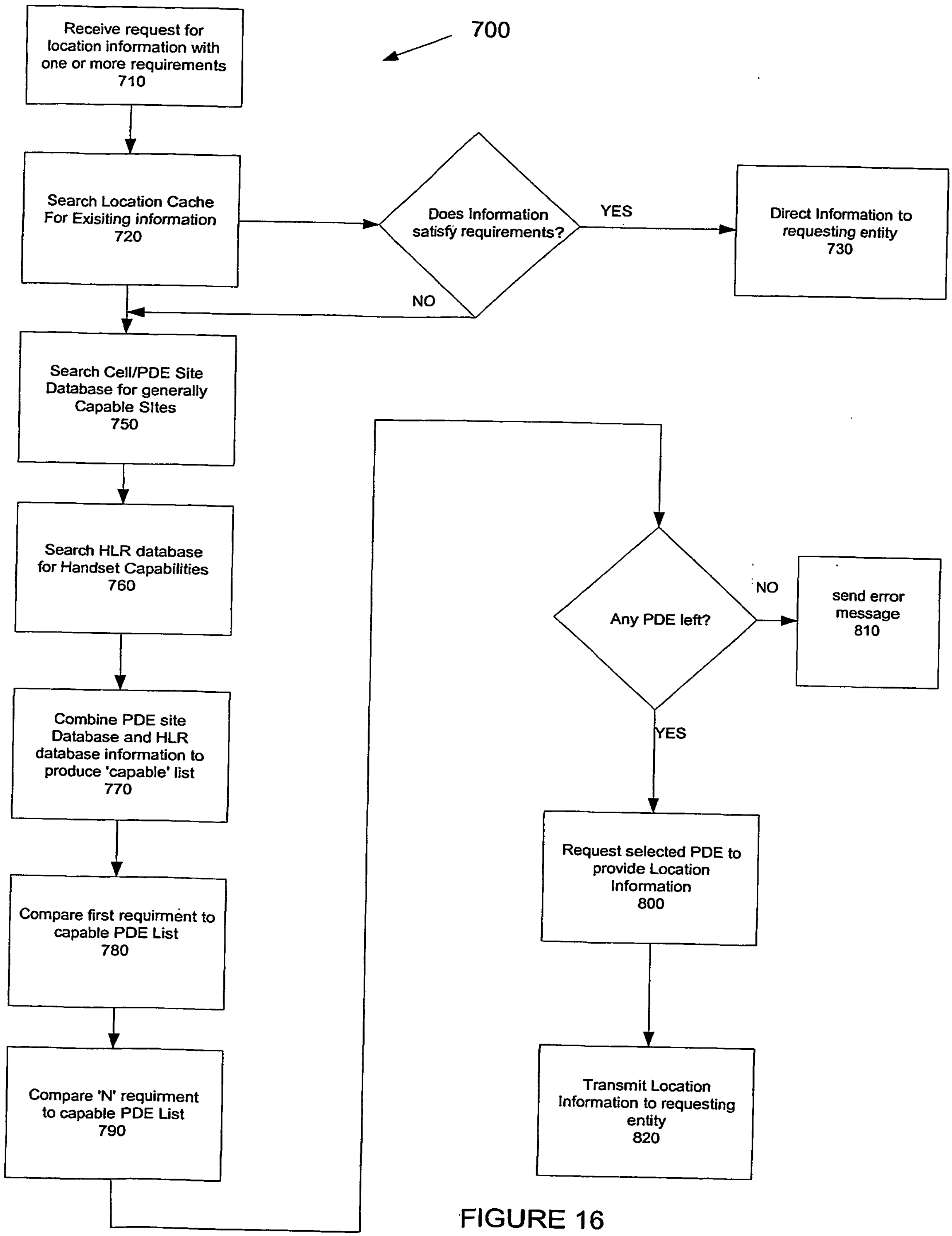

700
Receive request for location information with one or more requirements
710
Search Location Cache For Exisiting information
720
Does Information satisfy requirements?
YES
NO
Direct Information to requesting entity
730
Search Cell/PDE Site Database for generally Capable SItes
750
Search HLR database for Handset Capabilities
760
Combine PDE site Database and HLR database information to produce 'capable' list
770
Compare first requirment to capable PDE List
780
Compare 'N' requirment to capable PDE List
790
Any PDE left?
NO
YES
send error message
810
Request selected PDE to provide Location Information
800
Transmit Location Information to requesting entity
820

FIGURE 16

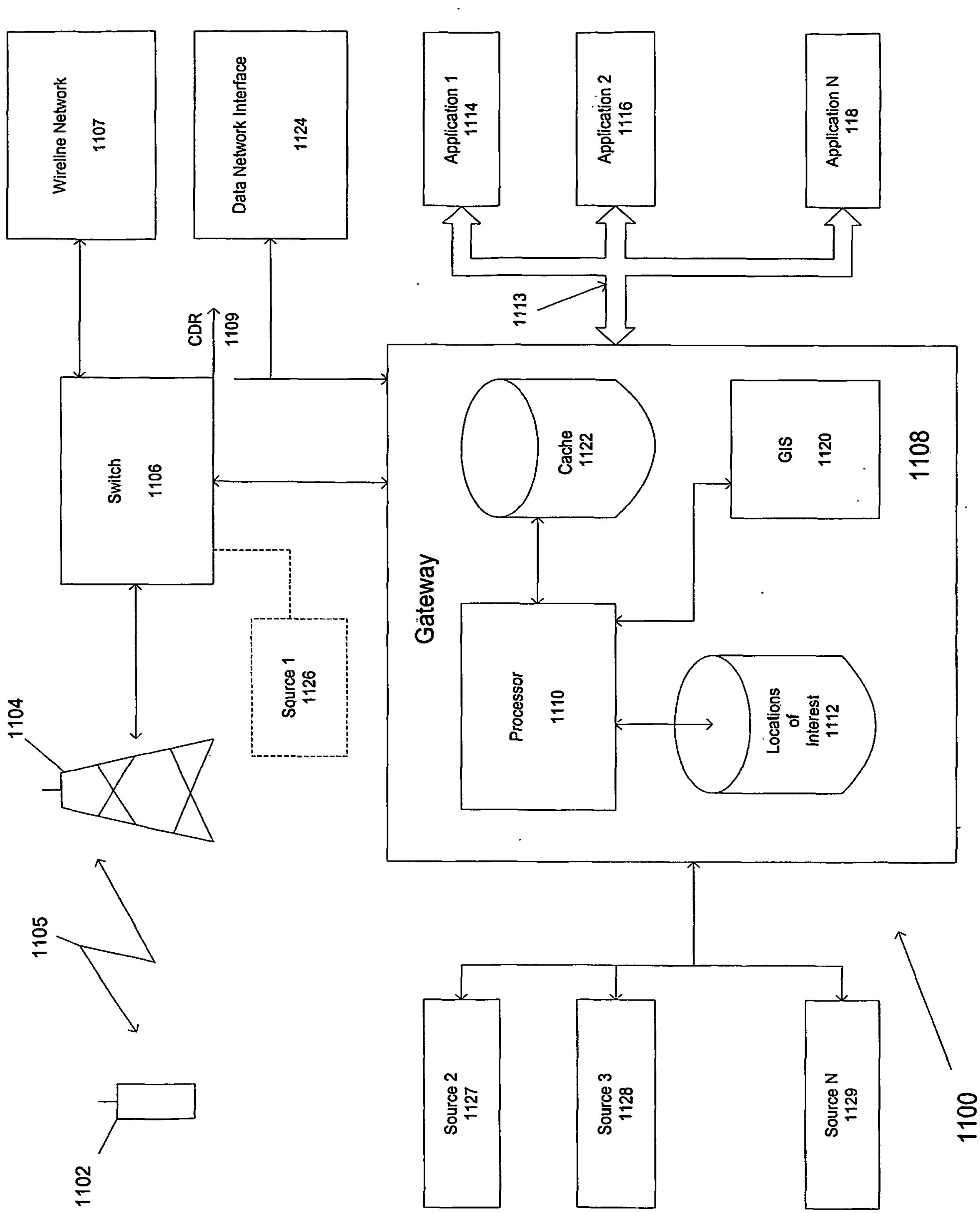

Wireline Network
1107
Data Network Interface
1124
Application 1
1114
Application 2
1116
Application N
118
1113
CDR
1109
Switch
1106
Gateway
Cache
1122
GIS
1120
1108
Processor
1110
Locations
of
Interest
1112
Source 1
1126
1104
1105
1102
Source 2
1127
Source 3
1128
Source N
1129
1100

FIGURE 17

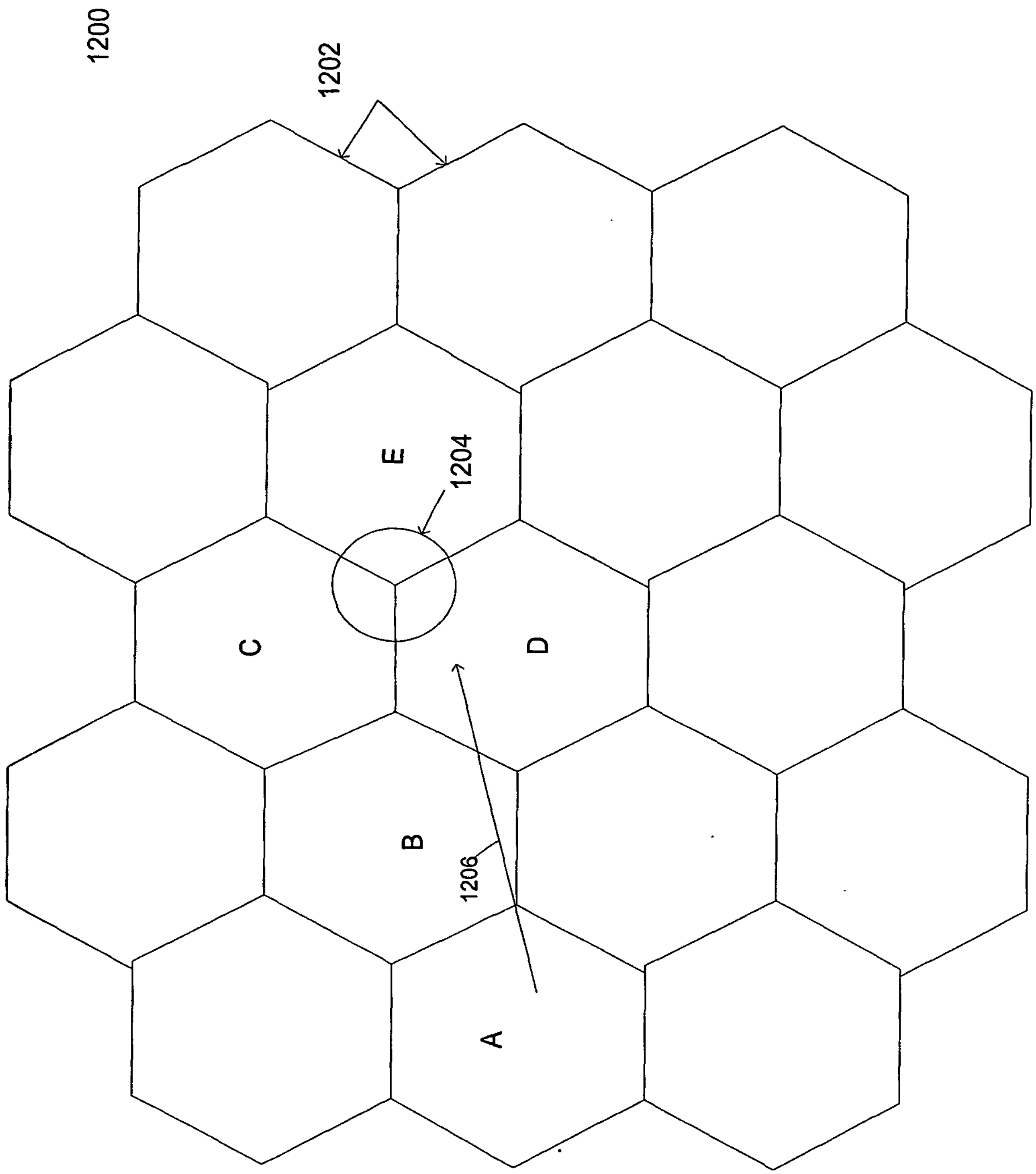



FIGURE 18

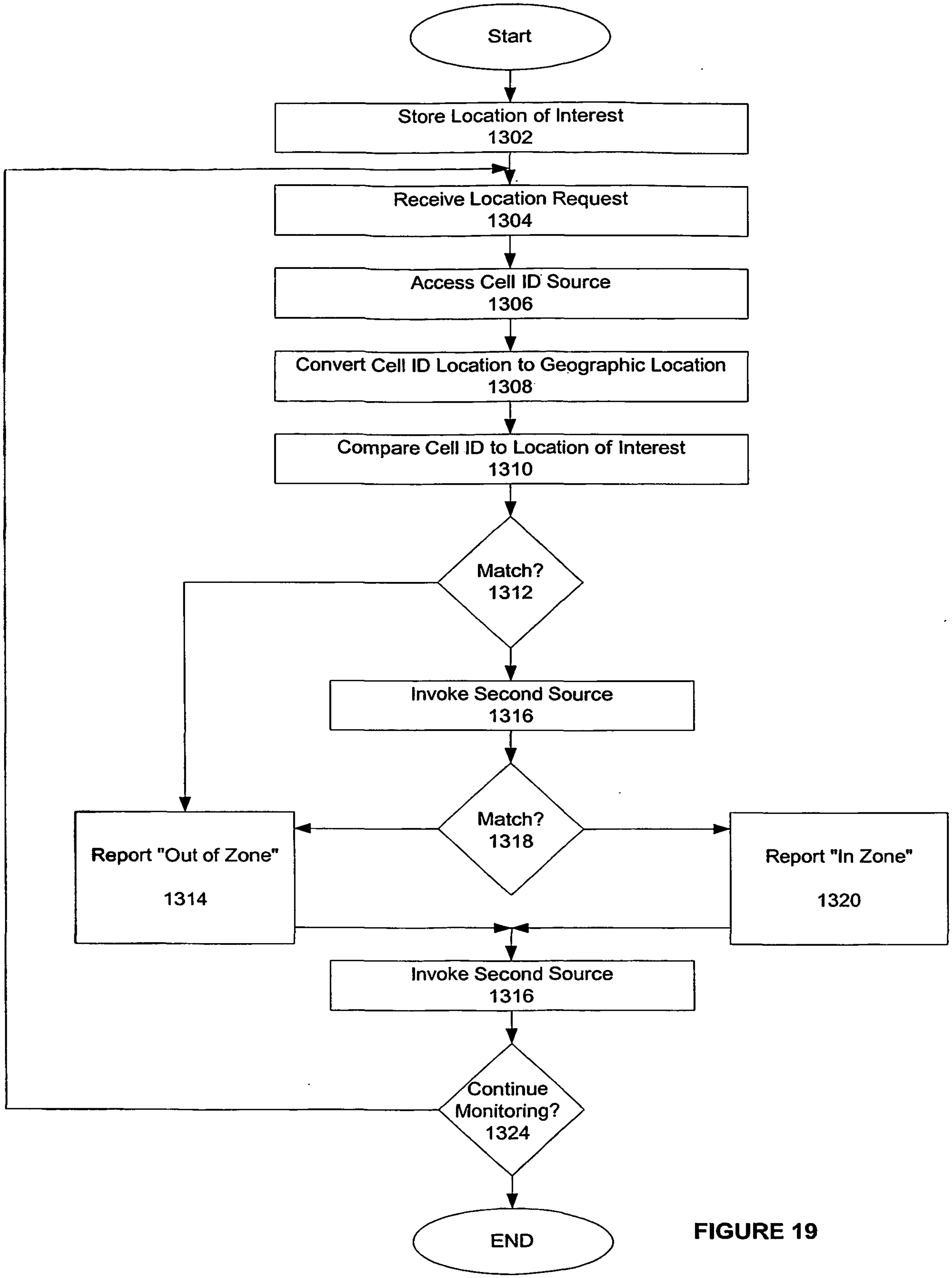
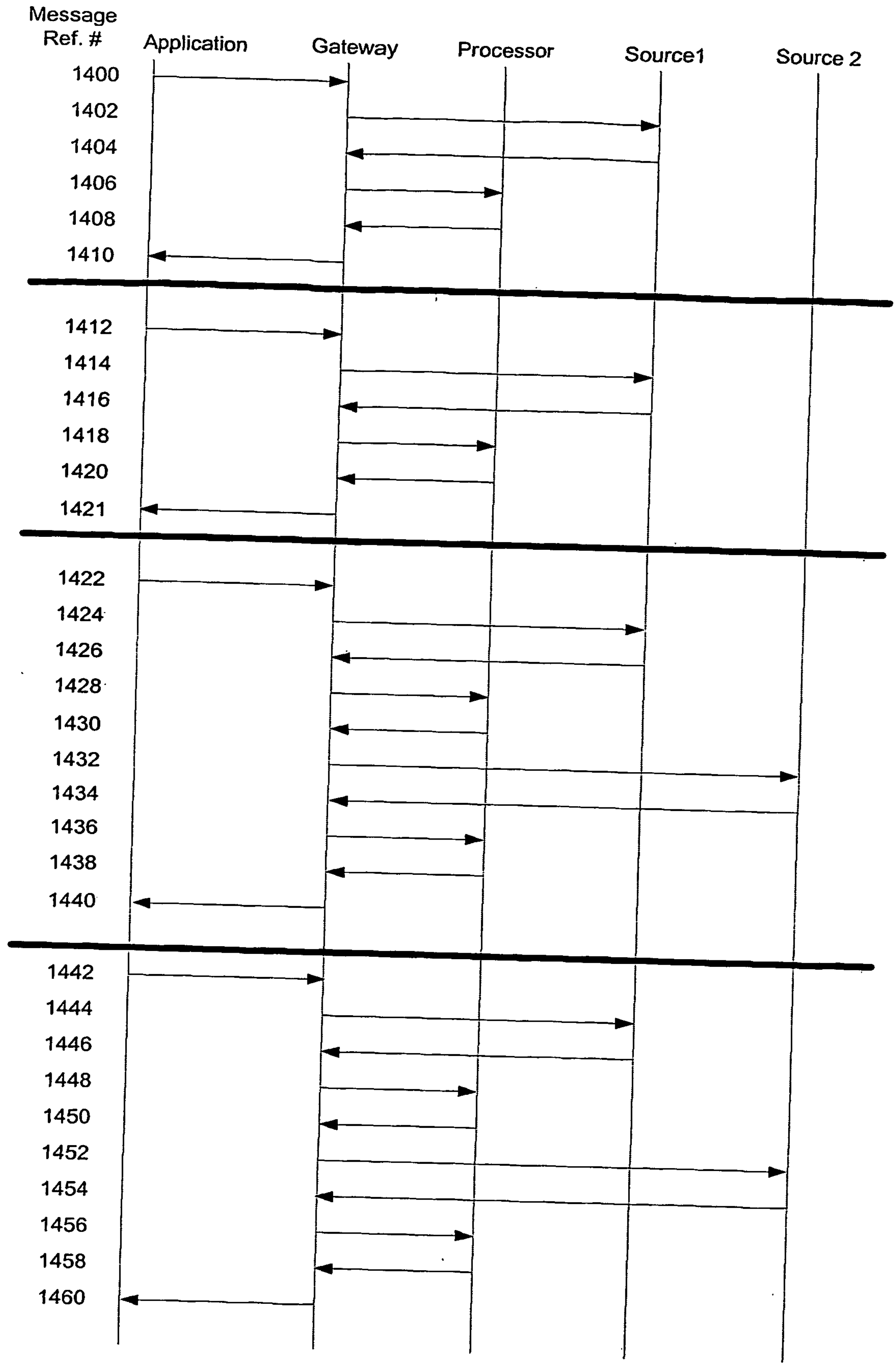

Start
Store Location of Interest
1302
Receive Location Request
1304
Access Cell ID Source
1306
Convert Cell ID Location to Geographic Location
1308
Compare Cell ID to Location of Interest
1310
Match?
1312
Invoke Second Source
1316
Report "Out of Zone"
1314
Match?
1318
Report "In Zone"
1320
Invoke Second Source
1316
Continue
Monitoring?
1324
END

FIGURE 19


Message Ref. #
Application
Gateway
Processor
Source1
Source 2
1400
1402
1404
1406
1408
1410
1412
1414
1416
1418
1420
1421
1422
1424
1426
1428
1430
1432
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1458
1460

FIGURE 20

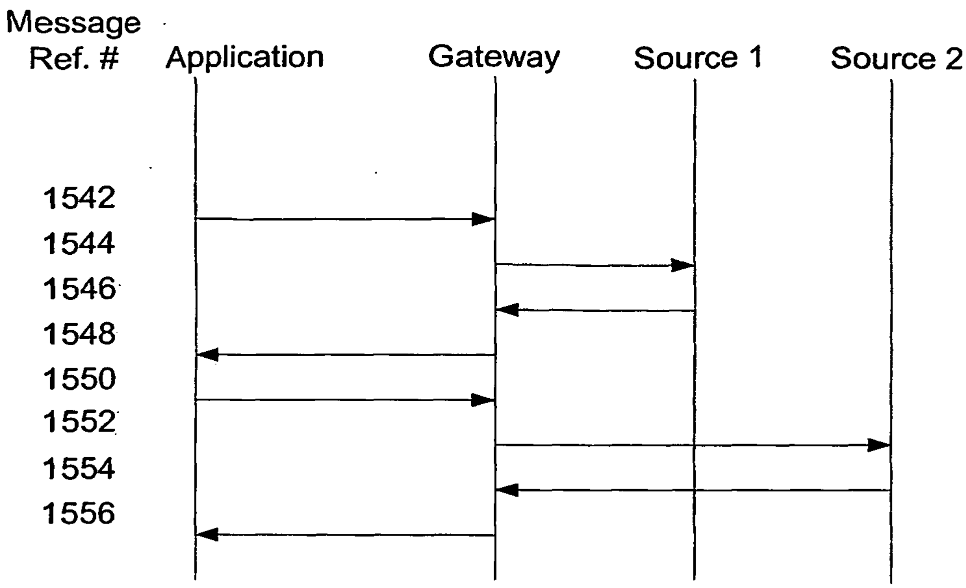
Message
Ref. #
Application
Gateway
Source 1
Source 2
1542
1544
1546
1548
1550
1552
1554
1556

**FIGURE 21**

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/06745

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC(7) : H04Q 7/20, H04B 7/00; H01Q 21/06
US CL : 455/456422,450; 342/357,442
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 455/456422,450; 342/357,442

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 5,166,694 A (RUSSELL ET AL) 24 NOVEMBER 1992 (24.11.1992), ABSTRACT, FIG.2, COL. 3, LINE 15-COL. 6, LINE 45 | 1-36 |
| Y | US 5,926,133 A (GREEN, Jr.) 20 JULY 1999 (20.07.1999) ABSTRACT, FIG. 11, COL. 3, LINE 45-COL.4 LINE 20, | 1-11 |
| Y | US 5,913,170 A (WORTHAM) 15 JUNE 1999 (15.06.1999), ABSTRACT, COL. 1, LINE 35-COL. 2, LINE 26, COL. 3 LINES 16-60, COL. 7, LINE 20-COL. 9, LINE 50, COL. 11, LINES 10-55 | 1-36 |
| A | US 6,108,555 A (MALONEY ET AL) 22 AUGUST 2000 (22.08.2000), THE WHOLE DOCOMENT | 1-36 |
| A | US 5,999,126 A (ITO) 07 DECEMEMBER 1999 (07.12.1999), THE WHOLE DOCOMENT | 1-36 |
| A | US ,6154,657 A (GRUBECK ET AL) 28 NOVEMBER 2000, THE WHOLE DOCOMENT | 1-36 |
| X,P | US 6,330,452 B1 (FATTOUCHE ET AL) 11 DECEMBER 2001 (11.12.2001), THE WHOLE DOCOMENT | 1-36 |
| X,P | US 6,282,427 B1 (LARSSON ET AL) 24 AUGUST 2001 (24.08.2001), THE WHOLE DOCOMENT | 1-36 |

[ ] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 01 May 2002 (01.05.2002) | 25 JUN 2002 |

| Name and mailing address of the ISA/US | Authorized officer |
|---|---|
| Commissioner of Patents and Trademarks<br>Box PCT<br>Washington, D.C. 20231 | KHAWAR IQBAL |
| Facsimile No. (703)305-3230 | Telephone No. 703-306-3015 |

Form PCT/ISA/210 (second sheet) (July 1998)